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What Promotes Interest in a Science Career Path?

Exploring Graduate Students and Postdoctoral Researchers' Descriptions of Their Interest
Development.

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What Promotes Interest in a Science Career Path? Exploring Graduate Students and Postdoctoral Researchers' Descriptions of Their Interest Development (Lourdes Guadalupe Malacara Estrada)

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Developments in Science, Technology, Engineering and Math (STEM) are essential to improve the way people live and they have a profound impact on the global economy. The lack of interest in STEM is resulting in a decrease in the number of people studying a degree in these areas. It is also threatening the engagement of people in science issues, which have an impact on society.

The aim of this qualitative study was to explore the experiences and reasons that have influenced the development of interest in science from the perspective of science graduate students and postdoctoral researchers. The research questions were: What type of interest-related reasons and experiences did the participants describe as influencing on their science career path development?, How the different types of interest-related reasons and experiences were situated in the different phases of their science career path? and What type of interest profiles can be found to lead to the science career path?

Ten science graduate students and postdoctoral researchers were interviewed to analyze their interest-related experiences and reasons through qualitative content analysis. The experiences were situated in the different phases of their career paths, encompassing both school and higher education years. In the analysis, the participants' descriptions were classified into categories to qualitatively identify different types of experiences that promoted interest in STEM. Finally, the career paths of the participants were compared to define different types of interest profiles that can lead to a science career.

The results indicated that interest-related experiences were associated with the context, the social network and with individual reasons. Most of the experiences were situated in university, followed by elementary school, high school, preschool and finally middle school. Also, four different profiles were found to lead to a science career path. In conclusion, the synergy of interest-related experiences provided by different contexts and significant people were essential to influence the development of interest in science. Therefore, collaboration between schools and families can be relevant to promote interest in science.

Keywords: interest in science; significant people; out-of-school factors; STEM

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1 Introduction

The research and advances in Science, Technology, Engineering and Math (STEM) benefit different aspects of life such as health and infrastructure (UNESCO, 2017) and promote the development of stable and stronger economies (Business-Higher Education Forum, 2011; Osborne & Dillon, 2008). Nevertheless, the statistics from the Organization for Economic Cooperation and Development (OECD, 2017) indicate that only 23% of tertiary education students among OECD countries are enrolled in a degree related to STEM, while 73% study business, humanities, social sciences, and education.

The development of interest in STEM is considered to be essential to increase the probability of more people selecting a career in these fields (Ainley & Ainley, 2015; Crowley, Barron, Knutson, & Martin, 2015; OECD, 2006). However, many countries are having problems to generate and maintain students' interest in pursuing a career in STEM (Osborne & Dillon, 2008; Thisgaard & Makransky, 2017), even though the employment rate is growing in these areas (Business-Higher Education Forum, 2011; UNESCO, 2017). A possible solution is the integration of STEM activities in learning environments (Ainley & Ainley, 2015). However, this requires that teachers and schools know how to generate and maintain interest in STEM (Ainley & Ainley, 2015).

Previous studies have focused on analyzing how students manifested interest in STEM during primary school, middle school, and high school (Jones, Taylor, & Forrester, 2011) and the factors that can influence their career choice. These studies have found that the support of families and teachers, and the instructional design of the classes play a significant role in the development of interest and the probabilities of studying a degree in STEM (Aeschlimann, Herzog, & Makarova, 2016; Oliver, Woods-McConney, Maor, & McConney, 2017).

However, only a few studies have explored the perspective of scientists and professionals in STEM, analyzing which interest-related experiences and reasons influenced the development of their science career pathways (Jones et al., 2011; Maltese, Melki, & Wiebke, 2014). These studies have found that out-of-school experiences, school experiences, teachers and parents influenced their interest in STEM (Dabney, Chakraverty, & Tai, 2013; Jones et al., 2011; Maltese et al., 2014; Sjaastad, 2012). In addition, it has been shown that the educational phases in which the interest is triggered and developed can vary (Maltese & Tai, 2010; Maltese et al., 2014). Nevertheless, further qualitative research is needed to explore the interest-related

reasons and experiences that influenced the development of interest in STEM from the perspective of people who have completed a degree in STEM and are working in the field (Maltese et al., 2014). Moreover, there is a lack of research focused on the population of STEM areas separately (Dabney et al., 2013).

In this study, ten science graduate students and postdoctoral researchers were interviewed with the aim of exploring the retrospective descriptions of the reasons and experiences that have influenced their development of interest in science. This was done by asking the participants to draw a visualization of their science career path as they saw it and situate on this visualization the crucial experiences and reasons that they considered themselves as meaningful in promoting their interest in STEM topics in general and science career particularly. Next, participants were asked to describe their interest-related experiences and reasons, and the way people influenced their science career path. Qualitative content analysis was applied to analyze the interest-related experiences and reasons described by the participants. The experiences were classified according to the phases in which they occurred. Furthermore, based on the analysis of these “time-stamped” experiences, different types of interest profiles were formulated that lead to a science career path.

2 Theoretical Framework

2.1 Interest

Interest is described as a psychological state (Hidi & Renninger, 2006; Järvelä & Renninger, 2014; Renninger & Pozos-Brewer, 2015) that predisposes an individual to reengage in a specific content over time (Järvelä & Renninger, 2014; Renninger & Pozos-Brewer, 2015; Renninger, Ren, & Kern, 2018). This predisposition can be also toward content learned in different contexts, and regardless of the learner's age (Hidi & Renninger, 2006). Interest is not a trait of a person, but it arises and develops from the interaction of the individual with the environment (Ainley, 2007; Renninger, Hidi, & Krapp, 1992).

Renninger and Hidi (2011) indicated that interest has five characteristics. First, interest occurs toward a specific event, content, or object (Renninger & Pozos-Brewer, 2015; Renninger & Bachrach, 2015). A learner can, for example, be interested in playing with a new chemistry set. Second, interest has a neurological foundation (Renninger & Pozos-Brewer, 2015; Renninger & Bachrach, 2015), as previous research in neuroscience has found that interest is associated with the brain's reward system (Berridge, 2012). Therefore, when the interest of a learner towards chemistry starts to develop, each opportunity that the learner has to engage in chemistry content becomes a reward for him or for her (Renninger et al., 2018). Third, interest has affective and cognitive components that interact through its development (Hidi & Renninger, 2006; Järvelä & Renninger, 2014; Renninger & Bachrach, 2015). For example, when interest in the subject starts, a learner can be excited to learn about chemistry experiments, even if his or her knowledge about chemistry is minimal (Renninger & Pozos-Brewer, 2015). However, the levels of affective and cognitive components can vary and tend to increase as the interest develops (Hidi & Renninger, 2006). Fourth, a person can be unaware of the interest that she or he has toward a particular content (Renninger & Pozos-Brewer, 2015; Renninger & Bachrach, 2015). For instance, a learner who is excited when studying chemistry can be unaware that he or she is starting to be interested in the subject, therefore it can be more difficult for him or her to engage in activities related to chemistry without the guidance of others (Renninger & Pozos-Brewer, 2015). Finally, interest is affected by the interaction between the person, the learning environment and other people (Järvelä & Renninger, 2014; Renninger & Pozos-Brewer, 2015; Renninger & Bachrach, 2015). The study of Dabney, Chakraverty, and Tai (2013) focused on analyzing the influence of family in the initial interest in science of PhD students and scientists

in the field of physics, showing that family fostered an earlier interest in science throughout science-related hobbies, science encouragement and the profession of the parents. Also, the opportunity to participate in activities related to a specific content (e.g. science) in the learning environments, helps to sustain the interest. For example, in a report on students' participation in STEM, Tytler, Osborne, Williams, Tytler, and Clark (2008) identified that one of the obstacles of the development of interest in science is the lack of science content and activities in primary schools and the lack of teachers' confidence to teach science content.

The development of interest has been divided into situational and individual (Harackiewicz & Hulleman, 2010; Hidi & Renninger, 2006). Situational interest can be momentary and a reaction to something specific (Harackiewicz & Hulleman, 2010). On the other hand, individual interest can be long-lasting, and the person can take it with him or her to different contexts (Harackiewicz & Hulleman, 2010). Earlier research has shown that family and the characteristics of the learning environment, are positively correlated to the levels of individual interest over time (Frenzel, Goetz, Pekrun, & Watt, 2010).

2.1.1 Interest Development

Based on previous research on interest, Hidi and Renninger (2006) developed a model that describes the development of interest in four phases (Figure 1). The first phases include situational interest (triggered situational interest and maintained situational interest) and the last two phases include individual interest (emerging individual interest and well-developed individual interest).

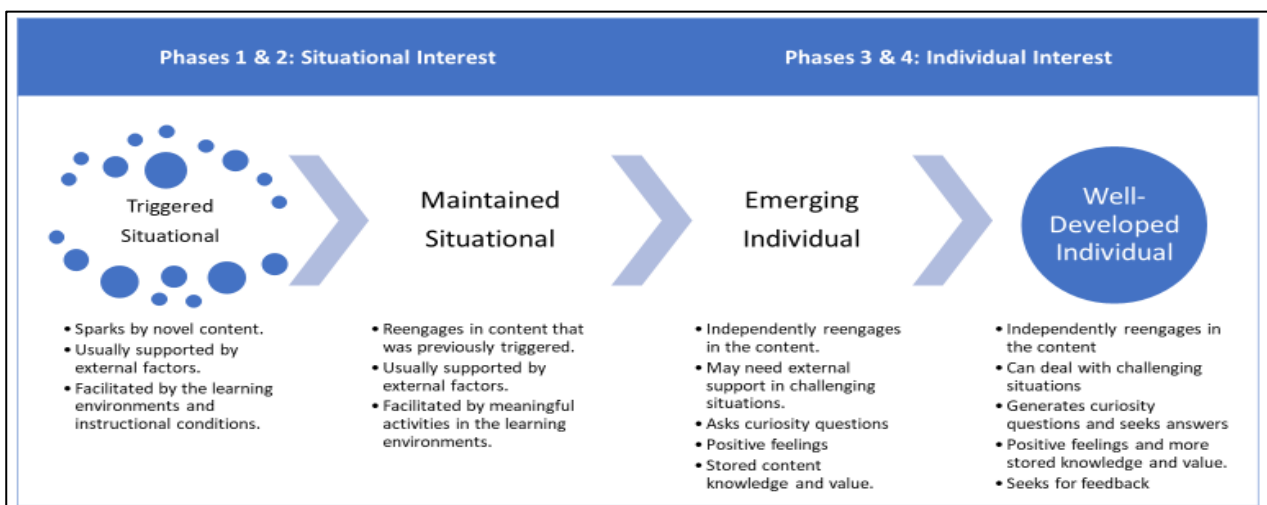


Figure 1 Four-Phase Model of Interest Development (Hidi & Renninger, 2006).

Triggered situational interest is initiated by a specific external factor such as an object, a person or an activity (Hidi & Renninger, 2006; Renninger & Pozos-Brewer, 2015). It can lead to maintained situational interest when it is kept over an extended period of time (Hidi & Renninger, 2006; Renninger & Pozos-Brewer, 2015). These phases need external support from the learning environment and the instructional design with meaningful learning situations such as hands-on activities, collaborative work, or project-based learning (Hidi & Renninger, 2006; Renninger & Pozos-Brewer, 2015). Renninger and Pozos-Brewer (2015) indicated that in maintained situational interest the learner starts to develop content knowledge and a sense of its value.

Emerging individual interest refers to the beginning of a predisposition to reengage with a particular content (Hidi & Renninger, 2006). The learner has positive feelings, stored knowledge and his or her own questions that makes him or her to search for answers (Hidi & Renninger, 2006; Järvelä & Renninger, 2014; Renninger & Bachrach, 2015). The last phase is well-developed individual interest in which the learner independently engage again in the content, generates more questions and seeks for answers (Hidi & Renninger, 2006; Renninger et al., 2018). The learner can cope with frustration and challenging situations by generating his or her own strategies to achieve his or her goals (Hidi & Renninger, 2006; Renninger et al., 2018). Content knowledge is a fundamental indicator of the development of interest, as the learner has a foundation to ask curiosity questions that facilitate his or her later reengagement with the content (Renninger & Hidi, 2015). Each phase of the model is considered as a foundation for the further development interest (Hidi & Renninger, 2006); nevertheless, the maintenance and develop of interest depends on internal factors and the external supports that a person receives (Renninger & Pozos-Brewer, 2015).

2.1.2 Triggers for Interest

A trigger is something or someone (e.g. an object, a person, a situation, etc) that is unexpected, and generates interest in a person by its novelty (Renninger et al., 2018). The interest for the trigger can be short-term or lead into a developed interest depending also on the response and support of external factors such as family and the opportunities they bring to reengage in similar content (Renninger & Bachrach, 2015).

The origin of the triggers varies. It can come from something that is happening in the context such as someone else watching a video of a new topic; from the learning environment (a

problem-solving case); or the trigger can be self-generated through the strategies that the learner adopts to deepen the understanding of a particular content (Renninger & Pozos-Brewer, 2015). Examples of triggers for interest in STEM are meeting a scientist, know what scientists do, or visiting a laboratory to understand more about their working environment (Ainley & Ainley, 2015).

Triggers for interest have an impact on both situational and individual interest. In situational interest, the triggers can affect the positive attitudes and motivation toward the content (Renninger & Su, 2012). In the study of Palmer (2009) the variety of activities in a science class as well as novel content influenced the levels of motivation of the learner. In individual interest, the triggers can help learners to persevere when working on challenging tasks (Renninger & Su, 2012). For example, the learner might be solving a complex problem of physics but perseveres because it is related to an individual interest such as soccer.

Triggering interest can happen regardless of age, gender or previous experiences (Renninger et al., 2018) and the triggers can direct the learner or the person toward a specific content (Renninger & Hidi, 2015). However, the same trigger can generate different influences on each person (Renninger et al., 2018) depending on the context, self-perception of his or her own skills, and the support provided by others. The interaction of these factors can lead to a positive or negative response toward the same trigger, influencing the further development of interest (Renninger & Bachrach, 2015).

2.2 Interest, STEM Learning and Science Career Path.

Research about the reasons that attracted people to STEM careers and the experiences that have affected their pathways, as well as the external support they have received, is still in progress (Marx, 2016). Previous studies have found that motivational aspects, interpersonal relationships, school-related experiences, and out-of-school experiences are associated with the development of interest in STEM (e.g. Aeschlimann et al., 2016; Alexander, Johnson, & Kelley, 2012; Dabney, Chakraverty, & Tai, 2013; Dabney et al., 2012; Maltese et al., 2014; Miller, Sonnert, & Sadler, 2017; Oliver et al., 2017; Sjaastad, 2012). The importance of motivational aspects such as self-efficacy beliefs, the interpersonal influences and the context-related experiences that can lead to a science career path are described below.

2.2.1 The Role of Motivational Aspects in Interest Development

In the field of learning sciences, interest is often linked with a wider motivational structure of the learner. Motivation in relation to learning is a broad construct that is composed of various motivational factors and sub-constructs and that in contrast to interest, is not linked to a specific content or domain but characterized by the learners' personal history and beliefs (Järvelä & Renninger, 2014). Motivation depends on the response of a person to the social and cultural contexts that surrounds him or her and how the interaction with these contexts can affect the person's mindset about his or her self-efficacy, outcome expectations, and his or her personal interests (Järvelä & Renninger, 2014; Renninger et al., 2018)

The positive correlation between motivational aspects, specifically, interest and self-efficacy, seems to be essential for deciding the career path to follow, especially in mathematics and science-related careers (Bong, Lee, & Woo, 2015). Self-efficacy refers to one's own perception of abilities and skills to learn and perform actions related to a specific domain (Bandura, 1997; Schunk & DiBenedetto, 2016).

Self-efficacy can be developed throughout different sources, including: actual performances, vicarious experiences, social persuasion and physiological indexes (Bandura, 1997; Schunk & DiBenedetto, 2016). Actual performances include the grades that a learner obtains, or the outcome of a project, and how the learner interprets these indicators and relate them to his or her own abilities (Schunk & DiBenedetto, 2016). A vicarious experience is referred to the opportunity to acquired information about individual's abilities and skills throughout seeing the success and performance of others (Schunk & DiBenedetto, 2016). Social persuasion includes the positive feedback that individuals receive about their performance and skills from significant people (Schunk & DiBenedetto, 2016). The last source, physiological indexes, involves the sensations of the body such as hand shaking or emotional states such as happiness, and how these indexes are perceived by the individual (Bandura, 1997; Schunk & DiBenedetto, 2016). The figure with the sources of self-efficacy is presented on the following page.

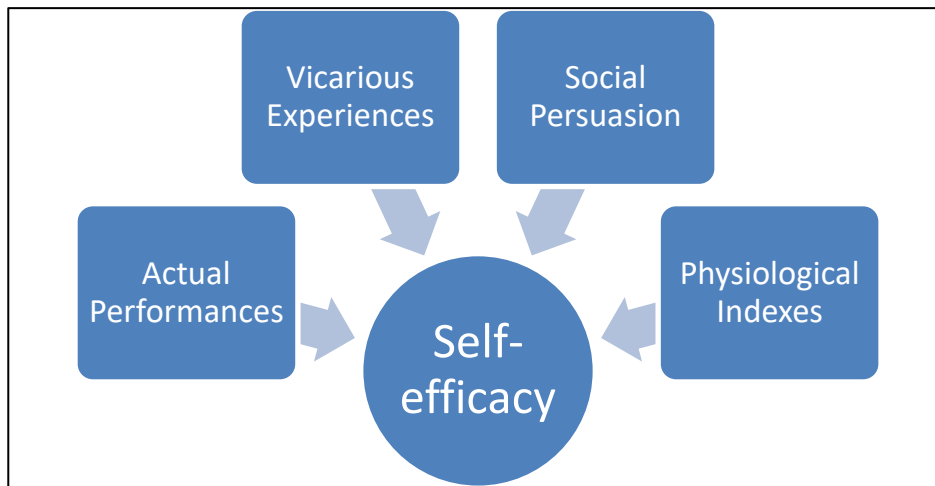


Figure 2 Sources of self-efficacy.

Individuals with high levels of self-efficacy tend to work harder, are more interested in learning, and usually achieve higher than individuals with low levels of self-efficacy (Schunk & DiBenedetto, 2016). Bong et al. (2015) reported the associations between interest and self-efficacy across different subjects in secondary school students. The findings indicated a strong relation between interest and self-efficacy in science and mathematics. Nevertheless, interest was more solid than self-efficacy, which suggested that successful experiences had a more significant impact on self-efficacy (Bong et al., 2015). However, a high level of self-efficacy is not enough to succeed if the individual is lacking the skills that are necessary for his or her area of interest (Schunk & DiBenedetto, 2016).

Interest and self-efficacy possess shared characteristics such as domain-specific and utility value, which can affect the outcome expectations of the individuals (Ainley, Hidi, & Berndorff, 2002; Bong et al., 2015; Schunk & DiBenedetto, 2016). If the individuals have a high self-efficacy and relate it to a developed individual interest, they will be confident to establish goals and look for opportunities to accomplish them (Bong et al., 2015; Schunk & DiBenedetto, 2016). Also, it will be easier to keep their interest even after a failure, as they know they possess the abilities necessary for succeeding (Bong et al., 2015; Schunk & DiBenedetto, 2016). The study of Sahin, Ekmekci, and Waxman (2017) analyzed how different experiences affected the choices of STEM college students. The results indicated that students with higher levels of self-efficacy in sciences more likely choose a STEM degree compared to those with lower levels of science self-efficacy beliefs.

However, even if the correlation among self-efficacy and interest is important, interest is also depending on the interactions with other people and the activities or tasks that the person accomplishes in different contexts such as in-school and out-of-school (Renninger et al., 2018).

2.2.2 Interpersonal Influences

Someone can be influential or significant if throughout a direct relationship or by being a role model, he or she can provide information that help to shape the self-perception that a person has or the perspective that this person has towards an object or topic (Sjaastad, 2012; Woelfel & Haller, 1971). In the study of Jones et al. (2011), engineers and scientists were interviewed to examine the experiences and people that influenced their decision to choose a career in STEM. Related to interpersonal influences, the results showed that parents and teachers play a significant role.

Woelfel and Haller (Woelfel & Haller, 1971) classified these significant people into definers and models. A definer is a person who provides relevant information about an object or about the self throughout a direct interaction (Sjaastad, 2012; Woelfel & Haller, 1971). For example, parents can be definers for their child if throughout conversations and discussions, they provide significant information that helps their child to identify his or her own abilities and interests. The models are the ones who, with or without direct interaction, influence a person by either being an example or by providing experiences related to an object or subject (Sjaastad, 2012; Woelfel & Haller, 1971). An example of a model is a teacher who creates interest in a topic of physics by going to a lab with the students and modeling a theory for them. As a result of these interactions, a person can be provided with either positive or negative experiences that influence the attitudes and decisions that he or she makes, including the career choice (Sjaastad, 2012; Woelfel & Haller, 1971). For instance, in the study of Sjaastad (2012) questionnaires of STEM students in higher education were analyzed in order to find the sources of inspiration for their educational choice. The quantitative and qualitative results suggested that interpersonal relationships especially with parents and teachers can be considered as key factors to encourage students to choose a STEM degree.

The attitude that students have toward STEM can be influenced by the interaction with significant people, whether they are definers or models (Sjaastad, 2012; Woelfel & Haller, 1971). The interactions with parents, teachers, and professors are seen as the most meaningful in the development of interest in science of people studying or working in STEM-related fields

(Jones et al., 2011; Sjaastad, 2012). Teachers can play a significant role in promoting students' interest in STEM throughout meaningful learning experiences in school context that allow the students to explore these subjects by themselves (Sjaastad, 2012). Teachers can also model STEM topics for the learners, for example, showing the students how to make a chemical reaction (Sjaastad, 2012). Furthermore, parents can provide experiences that triggers and support interest in science in out-of-school contexts (Ainley & Ainley, 2015).

2.2.3 Context-Related Experiences.

Although interest is content specific, development of interest is not strictly bound to certain contexts. Instead, life experiences in different contexts can support the interest in the same content. In terms of developing an interest that goes beyond school, and promotes a career in a STEM field, Dabney et al. (2012) conducted a study to explore the connection between out-of-school time science activities and career interest in STEM. The results indicated that students who participated in science activities during out-of-school time such as science clubs, science-related reading and TV watching had a higher interest in selecting a STEM-related career in university.

A key outcome of school experiences is supposedly the trigger of interest in a topic that leads to pursue this interest in out-of-school contexts (Pugh & Bergin, 2007). However, this rarely occurs because part of the learning experiences in school often involve content knowledge that is perceived as difficult to apply in real-life situations (Pugh & Bergin, 2007).

To trigger and foster interest in the learners, the experiences in school should involve active learning through activities such as solving problems, experimenting, tinkering, group projects, discussions, and debates that allow the learners to explore the topics or contents for themselves (Jones et al., 2011; Pugh & Bergin, 2007). Nevertheless, the interest or lack of it, depends on the interaction among the learner and several elements that are present in a classroom, such as the subject, the topic, the type of activities, the teacher-student relationship, and the opportunity that the learner has to develop his or her ideas (Jones et al., 2011; Swarat, Ortony, & Revelle, 2012). Woods-McConney, Maor, and McConney (2017) interviewed female students in upper secondary school about the influences that were relevant for their interest in science. The findings indicated that teachers and the science culture of the school played a significant role in the decision of the students to enroll in courses of physics at upper secondary level. Aeschlimann, Herzog, and Makarova (2016) used data from an extensive standardized survey

to analyze how high school students' motivation can be increased in science related classes, and its impact on a possible career choice in STEM. The results of the study suggested that when the instructional design of the classes supports and fosters the motivation of students, the probability of selecting a STEM career increases.

On the other hand, out-of-school experiences usually involve motivational aspects, such as personal interest, as the individual has the free choice of selecting the activities in which he or she wants to spend his or her leisure time (Falk & Storksdieck, 2009; Jones et al., 2011). There are two types of out-of-school experiences: structured and unstructured. The structured out-of-school experiences are often associated with situational interest, as they are planned and supported by someone else, such as academic clubs and competitions (Dabney et al., 2012). Miller, Sonnert and Sadler (2017) studied the relationship between participation in STEM competitions and career interest in STEM in high school students. The results indicated that students who participated in STEM competitions showed more interest in studying a STEM degree after high school. Moreover, the relationship between the competition and the interest in a STEM-career is towards a specific domain.

In contrast, the unstructured out-of-school experiences are associated with individual interest, as the individual is the one who is taking the control of the situation without external guidance (Dabney et al., 2012; Maltese & Tai, 2010). Some examples of unstructured out-of-school experiences are tinkering with objects, reading fiction and nonfiction books, playing with educational toys, and playing outdoors (Dabney et al., 2012; Maltese & Tai, 2010). Nazier (1993) conducted interviews with STEM professors about the reasons that influenced their decision to pursue a career in STEM. The results indicated that long term hobbies such as tinkering, playing with science-related toys and collecting fossils influenced their decision to pursue a STEM career.

Regardless of the context, the learner should have the opportunity to be part of activities that allows him or her to ask questions and freely explore the topics in which he or she is interested (Pugh & Bergin, 2007). Furthermore, the more opportunities an individual has of accessing positive resources and experiences related to a specific topic in school and in out-of-school contexts and the synergy of them, the better are the chances for development of interest (Eccles & Gootman, 2002; Fredricks, 2011).

2.2.4 Previous Studies in STEM Interest.

Interest in STEM is a relevant topic to study due to the decreasing number of students enrolled in these areas (Ainley & Ainley, 2015; Business-Higher Education Forum, 2011). However, there are few studies that have analyzed how the different types of experiences and reasons interacted and how they influenced the development of interest in STEM from the perspective of people who have completed a STEM degree and are working in the field (Jones et al., 2011).

To understand the perspective of graduate students and PhD scientists, Maltese and Tai (2010) analyzed interviews to determine the sources that initiated their interest in science. The findings suggested that most of the participants were already interested in science before middle school, and that the initial source of interest for the majority was related to individual factors and school experiences. Maltese et al. (2014) used survey data to compare the experiences that generated and maintained interest in STEM and non-STEM fields. Their results indicated that school-related experiences were more significant at stages in which students spend more time in the school. The results also suggested that teachers and parents played a significant role in the development of interest in science.

The studies that have analyzed the perspective of people who already completed a degree in STEM have some limitations. For example, the study of Jones et al. (2011) was geographically limited to participants from a single country. Maltese et al. (2014) indicated the need to investigate rather from a qualitative perspective the characteristics of the experiences that their participants considered relevant in their STEM pathway. Maltese and Tai (2010) analyzed scientists' experiences from a qualitative perspective, nevertheless, the questions they asked varied depending on the interviewers. Moreover, most of the studies that analyzed the development of interest have focused on population from all areas of STEM, instead of looking for patterns or experiences in a specific one (Dabney et al., 2013).

Thus, further research is needed to explore and analyze from a qualitative perspective the reasons and experiences that influenced the development of interest in STEM areas separately. This was performed in the present study, by selecting the area of science. The perspective of people who have already completed a higher education degree was explored. Also, the interest-related experiences and reasons described by the participants were situated in the phase in which they took place to find and compare interest profiles that lead to a science career path.

3 Aim and Research Questions

The participants of this study are graduate students and postdoctoral researchers who have engaged in a science career path. The aim of this study is to explore their retrospective descriptions of the interest-related experiences and reasons that have influenced their development of interest in science.

The research questions for this study are:

RQ 1. What type of interest-related reasons and experiences did the participants describe as influencing on their science career path development?

RQ 2. How the different types of interest-related reasons and experiences were situated in the different phases of their science career path?

RQ 3. What type of interest profiles can be found to lead to the science career path?

4 Methods

To grasp a detailed understanding of the participants' experiences on interest development in science career paths, the current study uses qualitative research methods (Bazeley & Jackson, 2013). Qualitative research is applied to understand the perspective of the participants, and to explore, interpret, and analyze their experiences, beliefs, and opinions (Bazeley, 2013; Maxwell & Reaybold, 2015). For that reason, the researcher needs to be familiar with its own data and gain a deep understanding of it (Bazeley, 2013).

4.1 Participants

The participants in this study were three master's degree students, three PhD students and four postdoctoral researchers (N = 10, 6 females and 4 males) currently working or studying in the fields of biology (n = 8), and earth and atmospheric sciences (n = 2). The higher education background of the participants includes ecology, biochemistry, biotechnology, bioinformatics, physics and chemistry.

The age of the graduate students and postdoctoral researchers ranged from 23 to 40 years. They were invited to participate in the study by email or social media and were selected based on the criteria that they had completed at least a higher educational degree in a field related to natural sciences and that their current work or their studies were related to science. Participants were chosen because of accessibility and through snowball sampling.

4.2 Data Collection Procedure

The method for data collection for this study was an in-depth semi-structured interview with the focus on gaining the participants' self-elaborated perspective on their reasons and experiences in relation to their interest development (Creswell, 2012), while allowing them to ask for clarification of the questions if it is needed (Newby, 2010). The questions for the interview were formulated based on previous research studies about interest in science, technology, engineering, and math (e.g. Dabney et al., 2012; Jones et al., 2011; Maltese et al., 2014; Sjaastad, 2012). Following the designed interview protocol (Appendix 1), participants were asked to mark on a timeline the experiences that made them interested in science using keywords or sentences, to retrieve their memories (see example in Figure 3). Afterwards, participants were asked to describe the experiences in their childhood, adolescence and

adulthood that made them interested in science. Moreover, they were asked about the time when they decided to pursue a degree in a science-related field. Also, they were asked about the people who contributed to the development of their interest, and the characteristics they think that someone working or studying science should have. During some of the interviews, the order of the questions was changed according to the answer of the participants, and some additional questions were asked to obtain more information about some of the experiences. Participants used the information they provided in the timelines (e.g. keywords, short sentences) as a reference during the interviews.

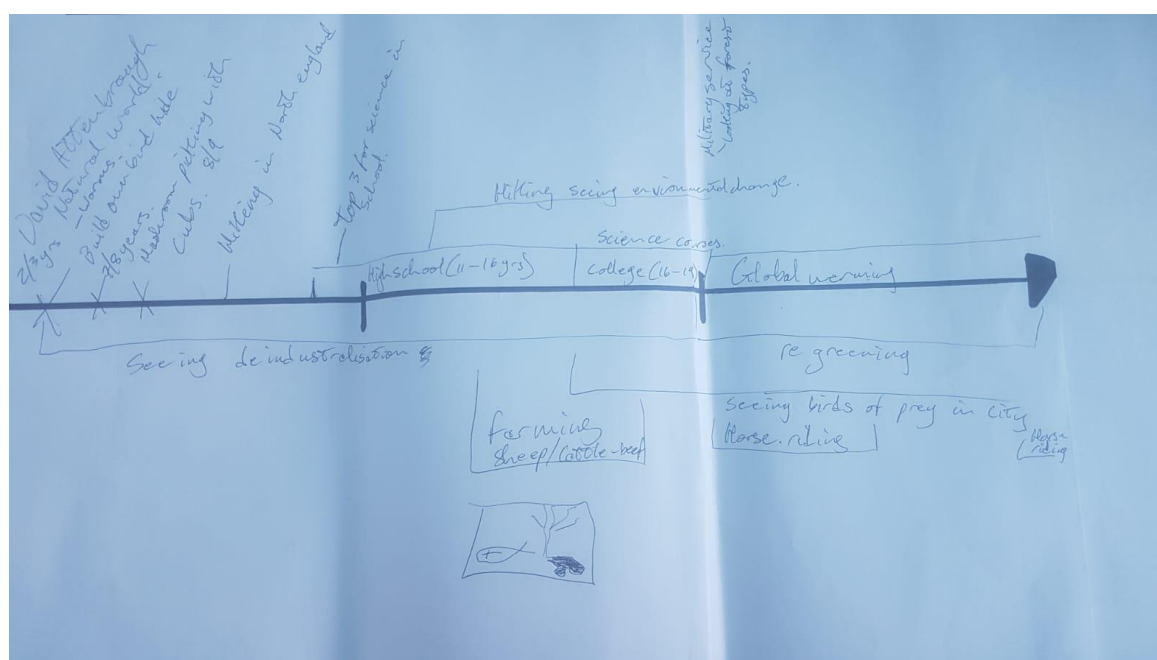


Figure 3 Example of a timeline created by a participant.

A pilot study was conducted to identify flaws in the interview and to make the necessary changes of the protocol. After implementing the changes and the suggestions from an expert, the data collection phase was started. Nine interviews were conducted face to face and one through a videocall. All interviews were audio recorded with previous consent of the participants. The interviews lasted between 30 and 90 minutes, with an average of 45 minutes.

4.3 Data Analysis

Qualitative content analysis was implemented to analyze the data. The first phase consisted in the transcription of the data, reading it several times, taking notes and writing down initial ideas

for the categorization based on the existing data and previous studies. The unit of analysis was meaningful episodes, which required the strong familiarity that was gained throughout the first phase (Drisko & Maschi, 2015). The length of the episodes varied from few to several sentences.

The initial coding categories were interpersonal relationships, out-of-school experiences, and in-school experiences based on Jones et al. (2011) and self-efficacy beliefs and individual interests, based on Bong et al. (2015). During the initial coding, the category nature-related experiences and goals emerged from the data.

In the second phase of the analysis, the category interpersonal relationships and its subcategories were modified into “significant people” based on the study of Sjaastad (2012) to identify the ways in which people can influence the participants’ decisions about their career pathways. The subcategories of out-of-school experiences were based on the results of the study of Dabney et al.(2012), but also adapted according to the data. The subcategories of in-school experiences were initially data driven, and redefined based on the subcategories of Jones et al. (2011). The subcategories of natural-related experiences emerged from the data.

Considering that a meaningful episode can include elements from different categories, the episodes were coded under every category that was relevant, and the researcher coded them several times to increase the reliability. The final themes, categories and subcategories used for the data analysis are presented in Figure 4.

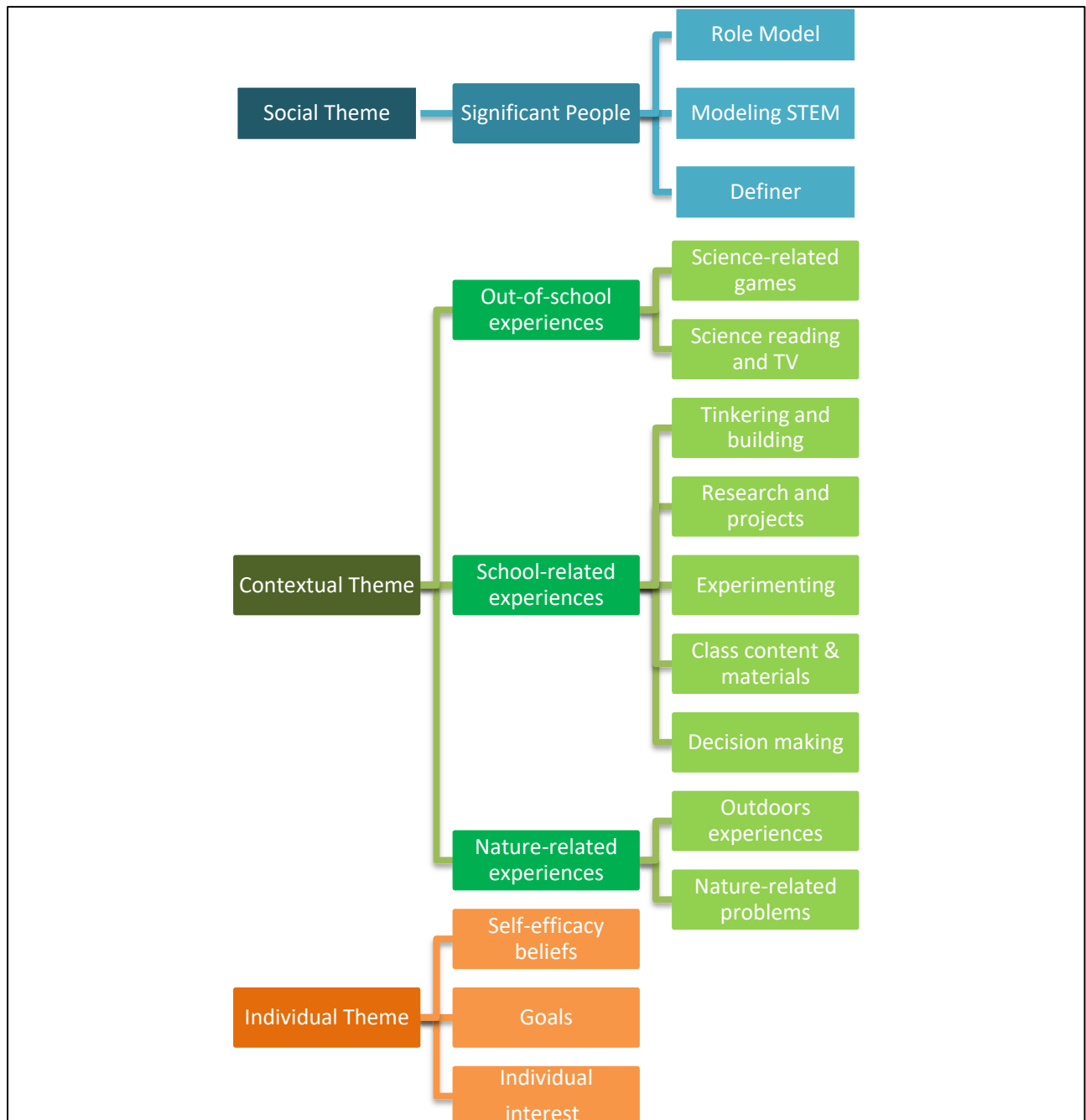


Figure 4 Final coding scheme including themes, categories and subcategories.

In the third phase, the complete coding scheme with definitions and examples was reorganized (see Appendix 2). The scheme without examples and 20% of the data were sent to an independent coder. Cohen's Kappa was measured and indicated a significant inter-rater agreement ($\kappa = 0,81$).

The principal researcher and the independent coder discussed about the coding scheme, and based on the feedback some minor changes to the definitions of two subcategories were made. The definitions of the categories and their examples are presented in the table below.

Table 1 Coding Categories and Definitions

Theme	Category	Definition	Example	Based on
Social	Significant people	A person who either through an interpersonal relationship or by being a model provide information or experiences that influenced the participant towards science.	“My parents...they provided me and the responsibility for me to question things or the platform for me to question things”	Jones, Taylor and Forrester (2011), Sjaastad (2012) and Woelfel and Haller (1971)
Contextual	Out-of-school experiences	Experiences not related to school that influenced the participant towards science.	“I read things that were related to science from those newspapers and then from some books that I borrowed from a library”	Dabney, Tai, Almarode, Miller-Friedmann, Sonnert, Sadler and Hazari (2012), Jones, Taylor and Forrester (2011), and data driven.
	School-related experiences	Experiences related to school that influenced the participant towards science.	“Yeah, it's like every science project. So, every year you have to build a different model. You could come up that using styrofoam to build the mitochondria.”	Jones, Taylor and Forrester (2011), Maltese & Tai, (2010), and data driven
	Nature-related experiences	Experiences related to nature that influenced the participant towards science.	“So, we did a lot of things in nature a lot of fishing and I brought it here as well that that fishing and other nature related experiences...with my parents”	Data driven

Individual	Self-efficacy beliefs	Perception of his/her own abilities and performance	“And then biochemistry I carried on, so I really enjoyed, and I was pretty good at that, so and I've never heard of it before I came to university”	Bong, Lee, and Woo (2015) and data driven.
	Goals	To have a purpose to be achieved.	“So, I wanted to be "academy valuable" to be able to raise my voice for what is right”	Data driven.
Individual	Interest	Independent predisposition to reengage with a content over time.	“Then in high school maybe I got these green values and got very interested about environmental problem problems and kind of how much there are different kind of environmental problems and I'm starting to think that what I could do more than that is maybe be the major waking up that I want to change the world”	Bong, Lee, and Woo (2015), Hidi and Renninger (2016) and data driven.

In the fourth phase of the analysis, the meaningful episodes were also coded and analyzed under educational levels to represent the different phases of the science career path in which the episodes took place. The educational levels were preschool and kindergarten, elementary school, middle school, high school, and university. Because some of the graduate students and postdoctoral researchers mentioned that some of the reasons had “always” been present, some of the episodes were coded under this label. This phase was done to answer the second research question “How the different types of reasons were situated in the different phases of their science career path?”.

In the last phase of the analysis, which served to respond the third research question (What type of interest profiles can be found to lead to the science career path?), the researcher compared the profiles of each participant by situating the interest-related experiences and reasons in a

timeline that encompassed the different phases of their science career pathways, including both school and higher education years.

Firstly, a timeline scheme was designed to situate the different interest-related experiences and reasons according to the educational level in which they occurred (Figure 5). Secondly, a timeline was created for each participant, in which the interest-related experiences and reasons were placed in the phase in which they occurred and subsequently marked with the colors corresponding to the category or subcategory (see Figure 4 for categories and color codes). The experiences or reasons that were "always" present according to the descriptions of the participants, were marked with an arrow across the entire timeline.

Thirdly, the profiles were compared according to the similarities between the types of interest-related experiences and reasons the graduate students and postdoctoral researchers described. As some of the profiles had revealed similar types of interest-related experiences, the subcategories were used to find more specific similarities. For example, if several profiles were describing school-related experiences, the subcategories were used to define if the descriptions correspond to class content or tinkering and building. After comparing interest-related experiences and considering the phase in which they took place, the profiles of the participants were grouped. Fourthly, each group of profiles was compared again considering the similarities between the types of interest-related experiences and the phases in which they occurred, to examine whether the individual profiles of any of the participants could fit into a different group. The profile of one of the participants was not classified into any group, because even if it had similarities with some groups, most of the experiences and reasons were different and situated in different phases compared with the others. Finally, a timeline per group of profiles was created, in which the similar interest-related experiences and reasons were represented under the name of the category or subcategory in which they were coded.

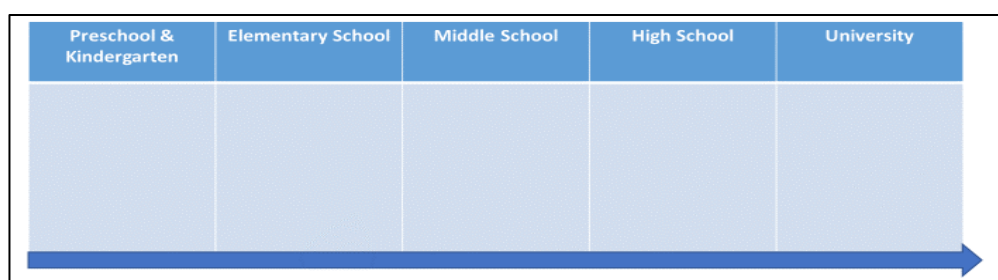


Figure 5 Timeline Scheme.

5 Results

5.1 RQ 1. What type of interest-related reasons and experiences did the participants describe as influencing on their science career path development?

Social, contextual, and individual interest-related reasons and experiences were described as influencing on the career path development in science of graduate students and postdoctoral researchers (Figure 6). The social theme was related to how significant people supported the participants in different ways such as being role models, modeling STEM, and as definers. The contextual theme included out-of-school experiences, in-school experiences and nature-related experiences. Lastly, the individual theme included goals, self-efficacy beliefs and their individual interests. Most of the interest-related reasons and experiences were contextual (46 %, $f = 112$), followed by social (35 %, $f = 85$), and lastly the individual reasons 19 %, $f = 47$).

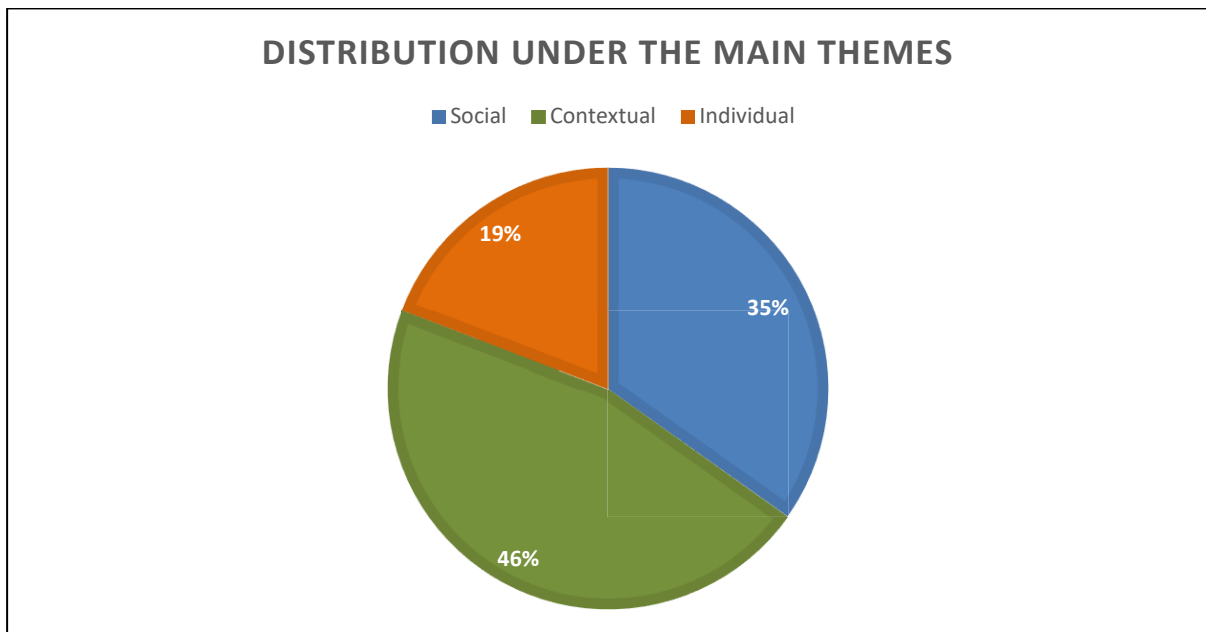


Figure 6 Distribution of the interest-related reasons and experiences under the main themes.

5.1.1 Social Theme

The graduate students and postdoctoral researchers described the social experiences and reasons that influenced on their science interest and their career path development. These experiences and reasons were coded in the category of significant people and its subcategories (Figure 7).

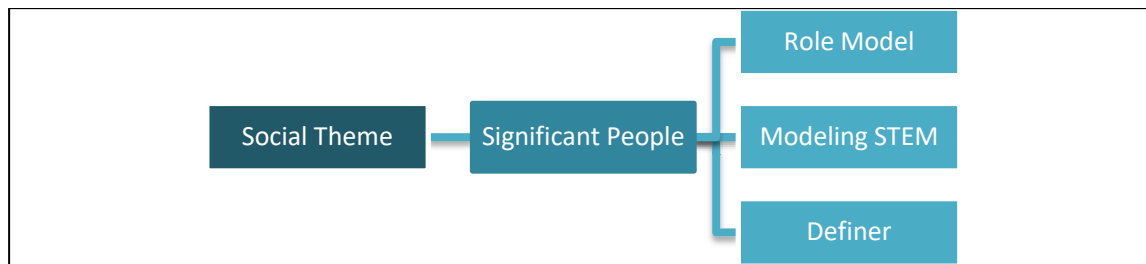


Figure 7 Categories and subcategories of the social theme.

Category: Significant People

In the category significant people, the three different sub-categories role model, modeling STEM, and definer describe the social experiences and reasons more precisely and were mentioned at similar frequencies (Table 2).

Table 2 Frequencies of the subcategories of significant people.

Category Significant people	Frequencies	Number of graduate students & postdoctoral researchers
Role model	33	7
Modeling STEM	21	10
Definer	31	8

Seven of the participants mentioned that the work and behavior of a role model was significant for them. One example is Clara, who described a famous primatologist as her inspiration, “I had always admired Jane Goodall for example, she worked with chimpanzee and she is still very outspoken about why is important the conservation of species and global warming”. Eight of the graduate students and postdoctoral researchers mentioned the importance of a definer who throughout a direct interaction provided information, guidance and the opportunity to discuss about relevant topics, “Well, also my dad. In a way that he likes to talk about science and environmental problems and those sorts of things so probably that has also affected. It wasn't like I was asking because I knew already lots of stuff. So, we were really having just discussions mostly about pollution or climate change or something like that” (Amanda). All the graduate students and postdoctoral researchers mentioned the importance of a person who provided information or an experience of modeling STEM that did not always require a direct interaction:

“So more particularly physics because there were teachers used to do experiments in class, not just teach science, experiment. They would play with magnet. So, take some chemicals

and show some chemical reactions... all stops burning in different color[s] and explain why different things going in different colors or how certain magnets work in certain way or how magnetic field line happen work. And all those things there were scientific experience” (John)

According to the results, the majority of the significant people were family members, teachers and professors, classmates and colleagues (85%, $f = 72$), while the category others included sweethearts, friends, bosses, famous scientists, and activists (15%, $f = 13$) (Figure 8). Half of the references of family members were considered definers ($f = 11$), 32% were modeling STEM ($f = 7$), and only 18% belonged to role models ($f = 4$). In contrast, 47% of the teachers and professors belonged to the subcategory of role models ($f = 20$), 33% were definers ($f = 14$) and 21% were modeling STEM ($f = 9$). Related to classmates and colleagues, 57% were definers ($f = 4$), 29% were role models ($f = 2$) and only 14% of the references were considered role models ($f = 1$). Most of the references that belonged to other significant people (e.g. sweethearts, famous scientists), were considered role models (54%, $f = 7$), followed by modeling STEM with a 31% ($f = 4$), and only the 15% ($f = 2$) were considered as definers.

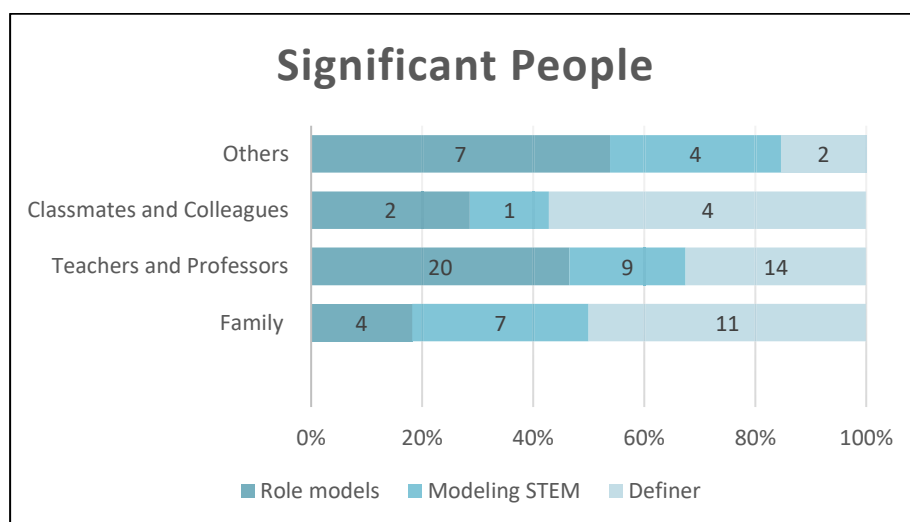


Figure 8 Distribution of the roles of the significant people.

5.1.2 Contextual Theme

The graduate students and postdoctoral researchers described the experiences and reasons that influenced their interest towards science and that were related to different contexts. These interest-related experiences and reasons were classified under the categories out-of-school experiences, school-related experiences, and nature-related experiences. The categories and subcategories of this theme are presented in Figure 9.

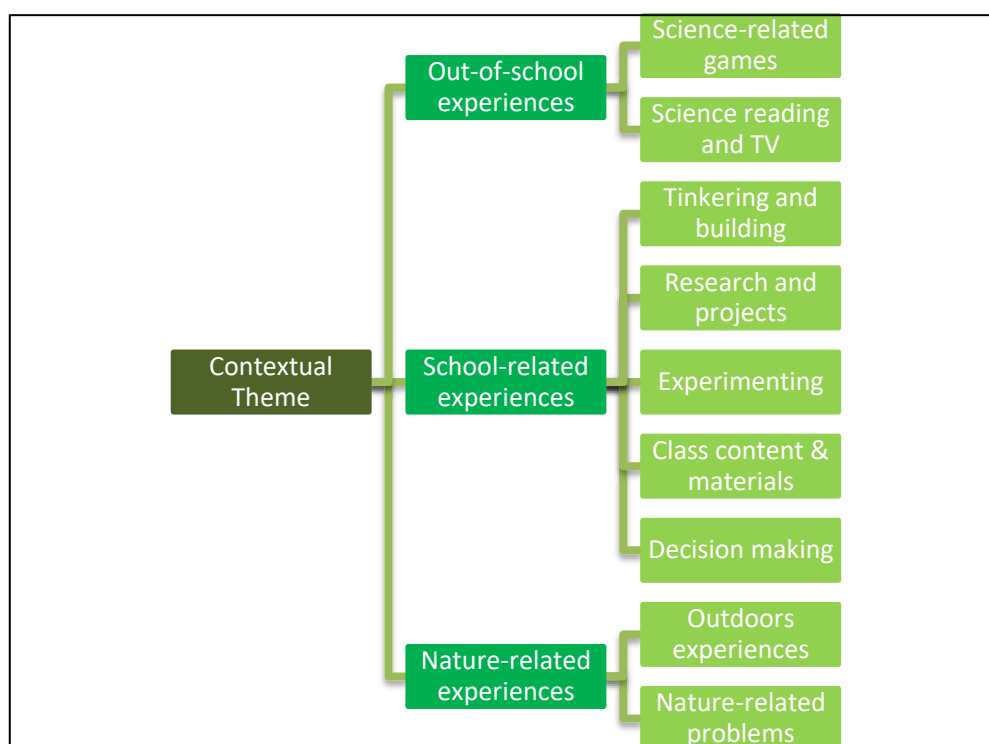


Figure 9 Categories and subcategories of the contextual theme.

Most of the interest-related experiences and reasons in the contextual theme were coded under the category school-related experiences, followed by nature-related experiences and lastly, the out-of-school experiences (Figure 10).

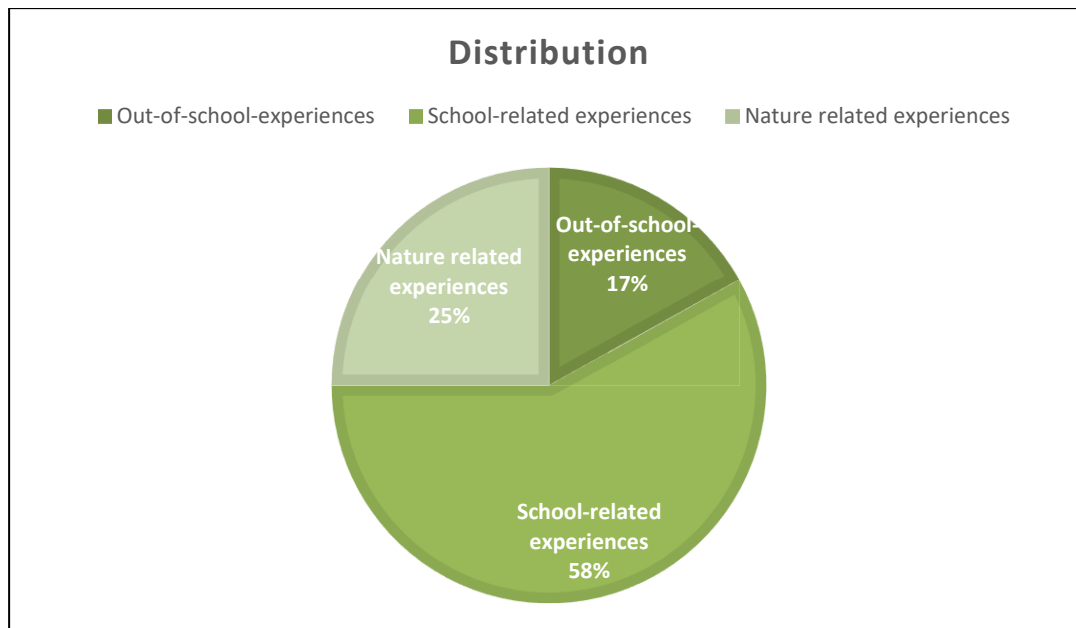


Figure 10 Distribution of the frequencies in categories coded under the contextual theme.

Category: School-related experiences.

The school-related experiences that influenced the career path of science graduate students and postdoctoral researchers were tinkering and building, research and projects, experimenting, class content and materials, decision making, and others (Table 3). The experiences that included the opportunity to tinker or build something were often associated with specific events that occurred once in the scholar year, for example science fairs, such as the one described by Melissa:

“So, every year you have to build a different model. You could come up using styrofoam to build the mitochondria. I think once we made solar panel-based hydroelectricity, so it was quite complicated, but that was when we were in sixth grade. And I think that's interesting because even a sixth grader can come up with a very complex design. If they're taught how to do it” (Melissa).

Table 3 Frequencies of the category school-related experiences and its subcategories

Category School-related experiences	Frequencies	Number of graduate students & postdoctoral researchers
Tinkering & Building	5	3
Research and projects	15	5
Experimenting	13	7

Class content & materials	17	7
Decision making	11	7
Others	4	3

Experimenting was often described as a practical ("hands-on") way to apply theoretical knowledge, which made them "curious" and "come up with your own ideas", like Lucas mentioned: "It's just curiosity. You can make your own aspirin paracetamol. That type of stuff and make caffeine extracts then". Graduate students and postdoctoral researchers recalled that the opportunity of doing research or small projects was significant and made them feel "satisfied" and "happy", and also aware about how experiments are conducted, regardless of the results they obtained. For example, Patricia explained about a project she attended during her undergraduate studies:

"We had to get all the project on using this banana peel as a prebiotic, so there are probiotic bacteria and if these bacteria can survive or make a room in this developing substrate. It was kind of a preliminary project, but I really enjoyed it... maybe we didn't get the results as expected but I liked working in it" (Patricia)

On the other hand, the interest of some of the participants was triggered by a novel content or relevant topic that was part of their classes or lectures, like Mariam, who was triggered by the disease Malaria due to "being such an important disease" or Patricia, who was interested in the human nervous system "I think that when we were studying the human anatomy and human structure and it was the human nervous system, was very interesting to me how our nodes work how voluntary things function like the heart always keeps beating, it never stops".

Graduate students and postdoctoral researchers also considered relevant that their schools or universities allowed them to decide some of the courses in which they wanted to enroll:

"When I studied for my bachelor and masters, we kind of had the opportunity to pick the minors and courses ourselves. So that was really good because that way I could really pick the things that I was most into. So, I had lots of interesting courses and I also went to field courses which are really good memories and important in my field" (Amanda)

Category: Nature related experiences.

Half of the graduate students and postdoctoral researchers considered that outdoor experiences influenced their interest in science. For example, Clara: “I remember when I was quite young, I used to play outside with ants. Like I would just observe their nest and I would just like spend hours looking at them. I always thought that animals were very interesting and plants”. Some of the participants (40%) were also aware of problems that affected the nature: “Then when I lived in a city where all the coal was burning...and the industry... quite gritty and urban. And the industry has its own aesthetic, but you think the health of yourself and the people and nature, then it's not good” (Lucas). Table 4 represents the number of graduate students and postdoctoral researchers that described ideas related to nature experiences, and its frequencies.

Table 4 Frequencies of the category nature-related experiences and its subcategories

Category	Frequencies	Number of graduate students & postdoctoral researchers
Nature-related experiences		
Outdoor experiences	18	5
Nature-related problems	10	4

Category: Out-of-school experiences

Graduate students and postdoctoral researchers considered science-related games, science reading and watching TV programs as influential experiences that took place out-of-school (Table 5). Four of the participants mentioned games or toys related to science with which they played, for example Edward, who described a science kit he used during his leisure time: “I also had a microscope. So, this box is more like...it's more for physics education. So, they have electronic components and also, they have something about optic. Yeah...like the lens”. For 80% of the participants, the subcategory science reading and TV was mentioned. They described that TV shows and science readings made them “curious” and were helpful to see science as “fun” and “tangible”, as the next experience described by Joseph:

“I did watch Bill Nye the Science Guy. So, he's a very famous science educator and he had this TV show when I was [a kid] and it was always aimed towards kids and introducing them to the scientific process. It was it was a fun show. ... But it's been it's been 20 years since I've seen it. It was something that made science tangible. You see people doing it and then it was made to look very fun, exciting” (Joseph).

John described how a book of questions made him realized that science was more than a subject:

“I still remember a book, it was titled "Why?, Why?, Why?", so the entire book was based basically about “why is that like that?” “Why does tadpoles have...? How? Why are these things like that? or Why do flowers..?, “Why does a sunflower...? or things like that. Things that you see in nature or things that you can see around you. So that was... kind of books like that which made science part of knowing your surrounding like science was not a separate topic” (John)

Table 5 Frequencies of the category out-of-school experiences and its subcategories

Category Out of school experiences	Frequencies	Number of graduate students & postdoctoral researchers
Science-related games	6	4
Science reading and TV	13	8

5.1.3 Individual Theme

Only 19% of the total of interest-related experiences and reasons were classified as individual theme. The interest-related reasons and experiences in this theme were coded in the categories: self-efficacy beliefs, goals and individual interests (Figure 11).

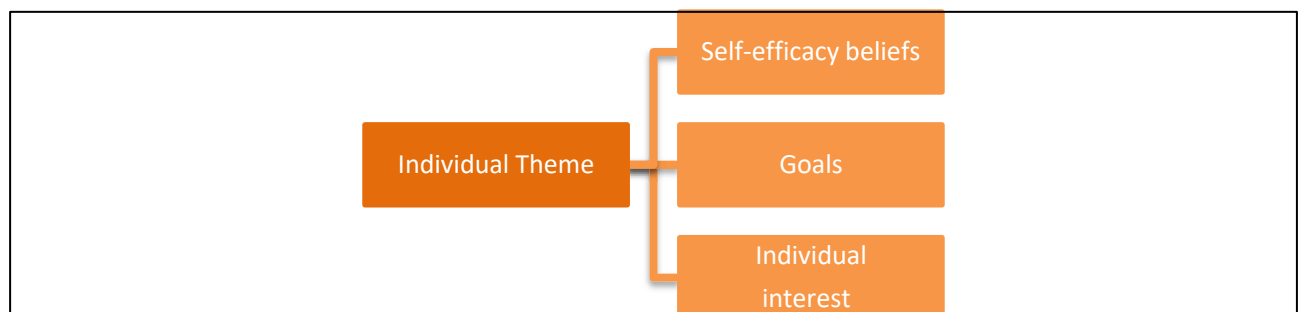


Figure 11 Categories of individual themes.

The frequencies in the three categories were similar (Table 6). The graduate students and postdoctoral researchers mentioned that their goals made them decide to pursue a degree related to science, for example Melissa who expressed: “I wanted to be "academy valuable" to be able to raise my voice for what is right”. Kate for example, decided to study biology based on her individual interests: “I want to do something which is more practical and closer to it than nature

itself. I'm closer to animals, plants and everything. So, at the time I kind of got the idea that maybe biology would be good for me”.

The episodes coded under the category of self-efficacy beliefs included the perception of the graduate students and postdoctoral researchers regarding their own abilities and performance in science. Mariam mentioned how her performance in biochemistry led her into science:

“Probably all stemmed from when I started doing biochemistry, and I was good at it. And because I really understood what was happening and it was easy, I could get more like into it, like really learn more and I think that promoted my interest and lead into doing science. I was probably 18” (Mariam)

Table 6 Frequencies of individual theme and its categories

Categories in the Individual Theme	Frequencies	Number of graduate students & postdoctoral researchers
Self-efficacy beliefs	13	5
Goals	16	8
Individual interest	18	7

5.2 RQ 2. How the different types of interest-related reasons and experiences were situated in the different phases of their science career path?

The reasons and experiences described to be influential for interest development by graduate students and postdoctoral researchers were situated in the different phases of their science career path. Half of the graduate students and postdoctoral researchers mentioned experiences in preschool and kindergarten that involved either contextual or social categories. All the participants described experiences in elementary school, middle school and high school that included categories of all the themes. In middle school, 40% of the graduate students and postdoctoral researchers mentioned experiences that involved social, contextual and individual reasons. Finally, 80% of the participants described individual or social reasons that have always been present in their lives. Most of the experiences and reasons were situated in university, followed by elementary school, high school, “always” present, preschool and kindergarten, and finally middle school. The figure below represents the frequencies of the interest-related experiences and reasons in the different phases.

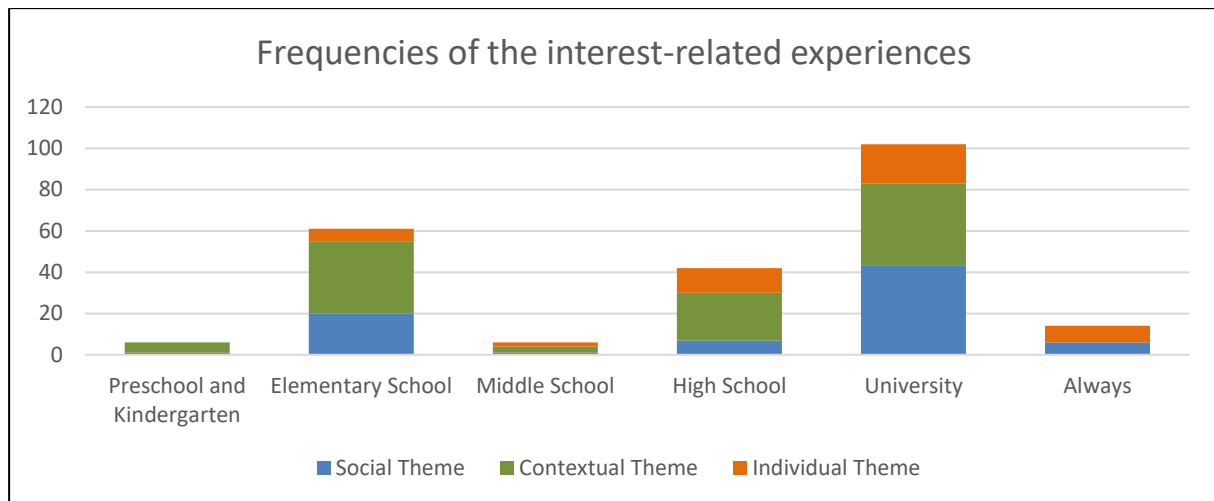


Figure 12 Distribution of the frequencies of the interest-related experiences and reasons in the different phases of their science career path development.

Preschool and Kindergarten

The majority of experiences in preschool and kindergarten were associated with the contextual theme (83%, $f = 5$) and the rest with the social theme (17%, $f = 1$) (Figure 13). The contextual experiences and reasons included the subcategories outdoor experiences (category: nature-related experiences) and science reading and TV. One example is Lucas, who used to watch TV programs about “natural world” and played outdoors as he mentioned: “I used to play with soil and other worms”. The social experiences and reasons were all associated with family members who took the role of definers or were modeling STEM. John described the role and influence his grandmother had when he was really young “My grandmother used to tell me stories...but one thing was if I had any question she always encouraged me to ask. So I think that was one of the starting points, like, that made me interested in to knowing more about stuff”.

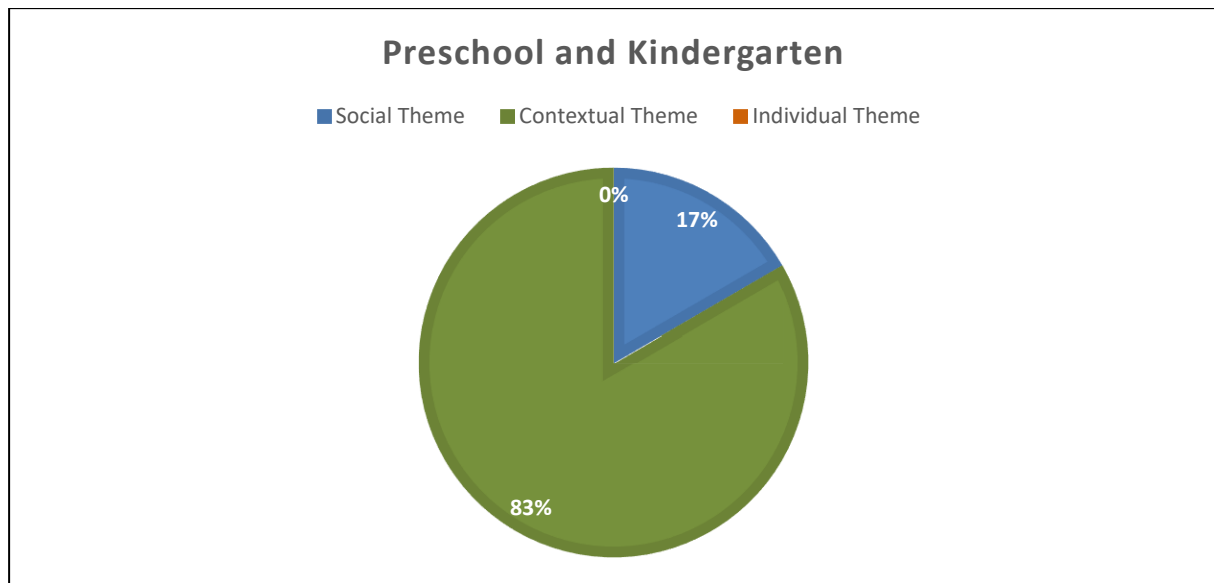


Figure 13 Distribution of the experiences and reasons in preschool and kindergarten according to the themes.

Elementary School

During the years in elementary school, the experiences and reasons mentioned by the graduate students and postdoctoral researchers were related to contextual (57%, $f = 35$), social (33%, $f = 20$), and individual experiences and reasons (10%, $f = 6$) (Figure 14). The contextual experiences and reasons were mostly associated with school-related experiences (40%, $f = 14$), followed by out-of-school experiences (31%, $f = 11$) and nature-related experiences (29%, $f = 10$). The school-related experiences included class content, experimenting, and tinkering, for example “when I was in fifth grade or sixth grade...we needed to make these motors...that we see this electrical wire...yeah you put on battery it will turn, right. We need to make these motors by ourselves” (Edward). The out-of-school experiences included mostly science reading and watching TV programs about science, but also knowledge about the problems that the nature is facing.

The graduate students and postdoctoral researchers described experiences that involved significant people (social theme) in this stage. Most of them were family members (58%) who were modeling STEM, definers and role models. The rest of the significant people were teachers (27%), classmates (10%) and others (5%). One example is Patricia, who explained the influence she experienced at home:

“First of all, in my family both my elder sisters were doing their bachelor's in science, in my family, everyone was in science. My father also studied science though he then worked in something different, but I had like in my family there were people and then, so I grew up seeing these things” (Patricia)

Lastly, some individual reasons were also mentioned, for example Kate, who pointed out her personal interest in solving problems: “Something which might be affecting on some level in a level that I was interested in kind of solving the problems. I was interested about if there were some kind of a problem, I wanted to solve it”.

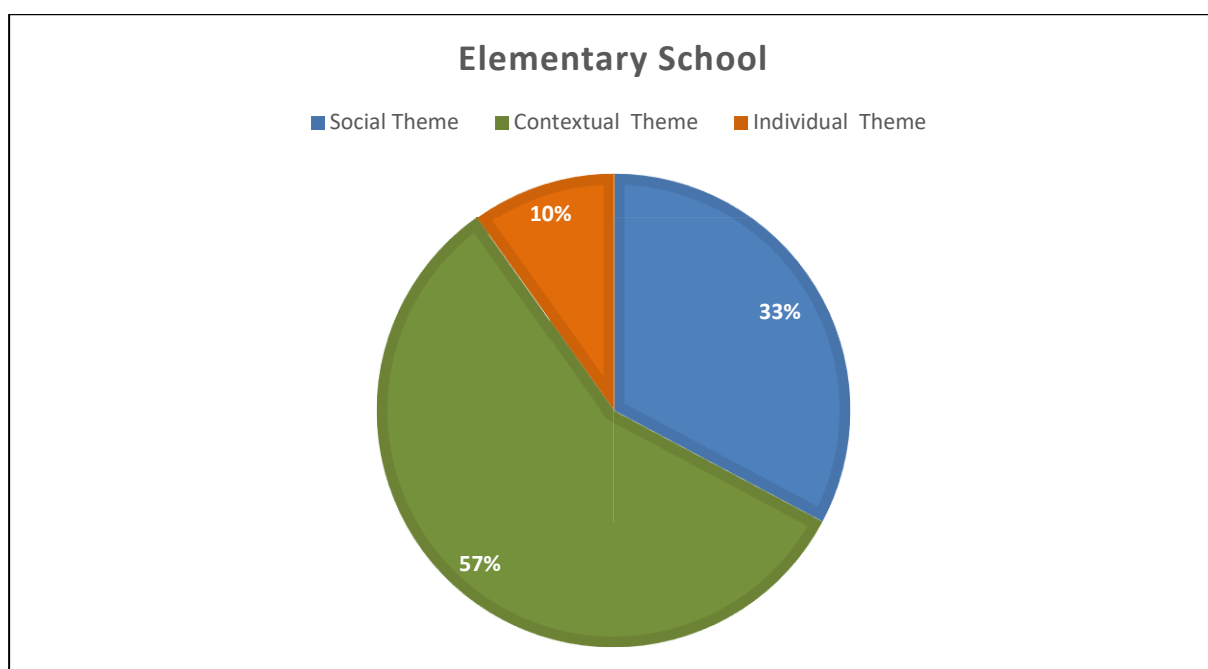


Figure 14 Distribution of the experiences and reasons in elementary school according to the themes.

Middle School

Middle school was the phase in which less interest-related experiences and reasons were mentioned. Half of the experiences and reasons in middle school were associated with the contextual theme (50%, $f = 3$) that included out-of-school related experiences and school-related experiences (Figure 15). One third related to the individual theme (33%, $f = 2$) including self-efficacy beliefs and personal interests, and the rest included experiences related to the social theme (17%, $f = 1$), specifically definers (Figure 15). An example of an experience related to the content of a class during middle school was provided by Melissa: “And that's when there

was a small part of genetic engineering, and that's what I wanted to do, I wanted to know more...”.

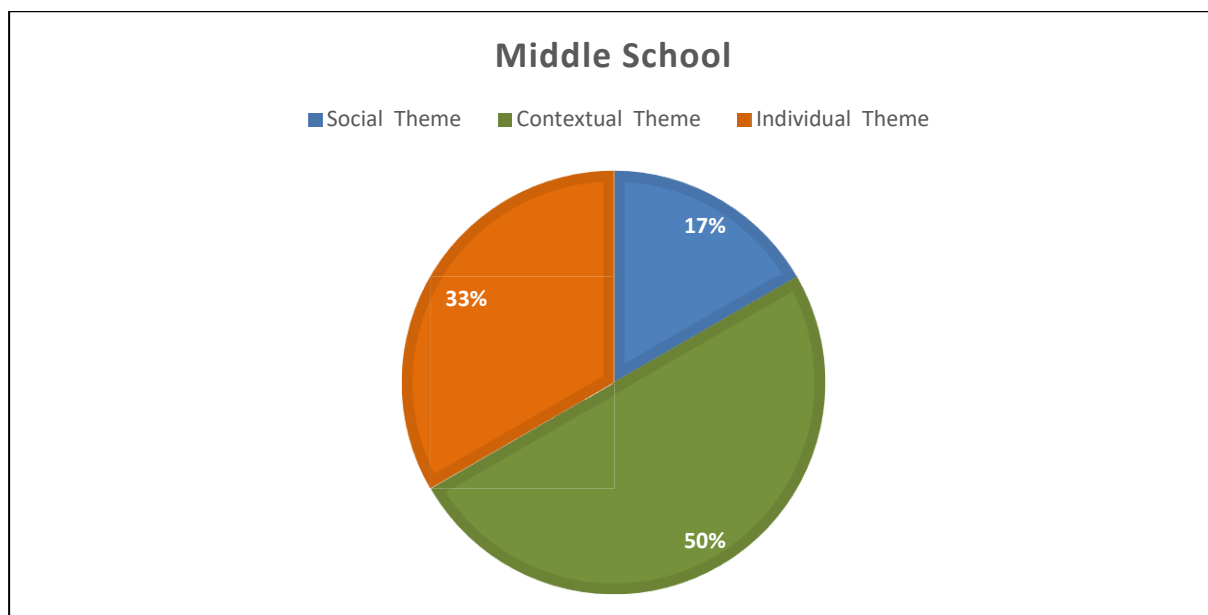


Figure 15 Distribution of the experiences and reasons in middle school according to the themes.

High School

During high school, the 55% ($f = 23$) of experiences mentioned by the undergraduate students and postdoctoral researchers were related to the contextual theme (Figure 16). The nature-related experiences included the knowledge of problems that involved nature. The out-of-school experiences involved science reading. The school-related experiences included class content and material, experimenting, research and decision making, as in some schools the participants had the opportunity to choose some of the courses by themselves. An example of an experience was provided by Patricia, who was interested in one of the topics of the class:

“I think we had to study these different plants have different families and different kingdoms and like how you distinguish one family from another, and we used to have this exercise is exercise that a particular family flower has a certain structure of support petals, so it's a kind of formula” (Patricia)

The individual theme represented 28% ($f = 12$), and included goals, self-efficacy beliefs and personal interests. In the case of John, he pointed out his goal: “I wanted to be a scientist, I wanted to get into that college”. Lastly, 17% ($f = 7$) of the experiences and reasons were related

to the social theme, which included teachers and family members as role models, as well as teachers and classmates as definers (Figure 16). An example of a significant person in high school was the geography teacher of Amanda:

“I had a really good geography teacher. So, she is actually the reason why I applied to study my bachelor's degree here at the university. So that had a huge impact. She probably just had a really good teaching style. She was a nice person and I guess she taught things through in an interesting way. She gave feedback from exams or if we had to write essays or something. So, I think she took some time to give everyone personal feedback” (Amanda)

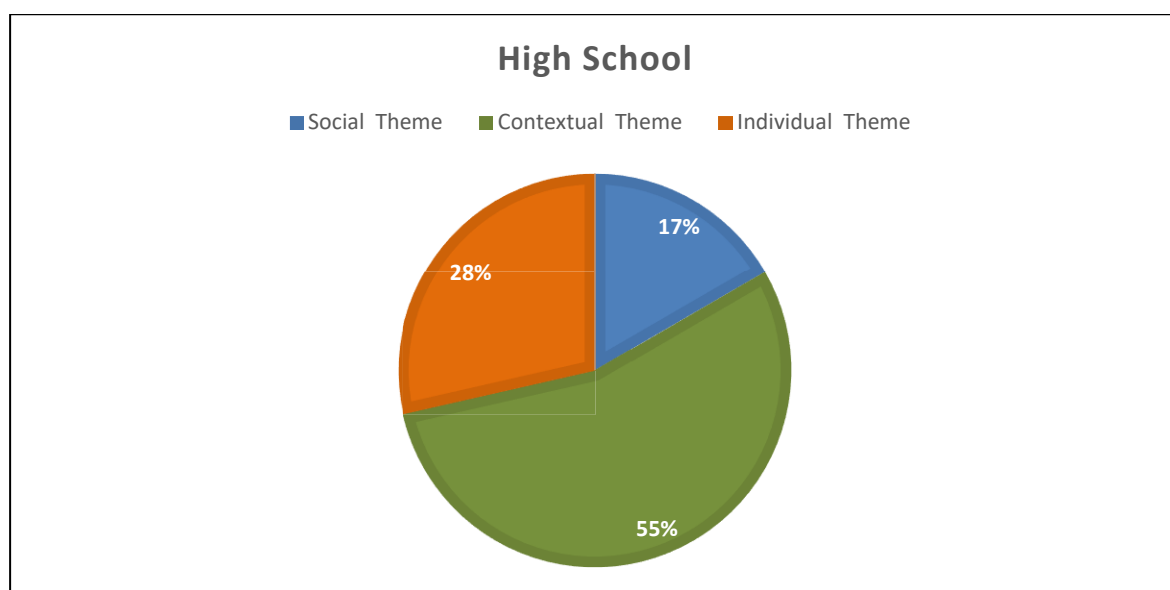


Figure 16 Distribution of the experiences and reasons in High School according to the themes.

University

During the years of university, 42% ($f = 43$) of the experience were related to the social theme (significant people), 39% ($f = 40$) to the contextual theme (school-related experiences, and nature-related experiences), and only the 19% ($f = 19$) to the individual theme (goals, self-efficacy beliefs, and personal interests) (Figure 17). The significant people in this stage included professors, classmates and famous scientists who were role models, modeling STEM and definers. Clara described why her professors in University were her role models: “it would have been in my bachelor’s years, my professors, because they were really passionate of that were doing and all that”.

The nature-related experiences in this stage included the knowledge of problems and outdoors experiences. The school-related experiences involved doing research, experimenting, class content and materials, and decision making. Mariam explained the influence of experimenting during her bachelor's years:

“So you are getting the lecture and the practical in, through the practices you actually don't necessary have to learn the theory because you kinda redoing it, but actually in a practical way, if you add this and that, this is what happen, but you can see it happened, and then you actually understand the theory better” (Mariam)

The individual theme included the categories goals, self-efficacy beliefs and personal interests, and one example is provided by Melissa: “I knew I wanted to work with proteins, and I knew I wanted to work with something that very few would. So, I knew the main aim”.

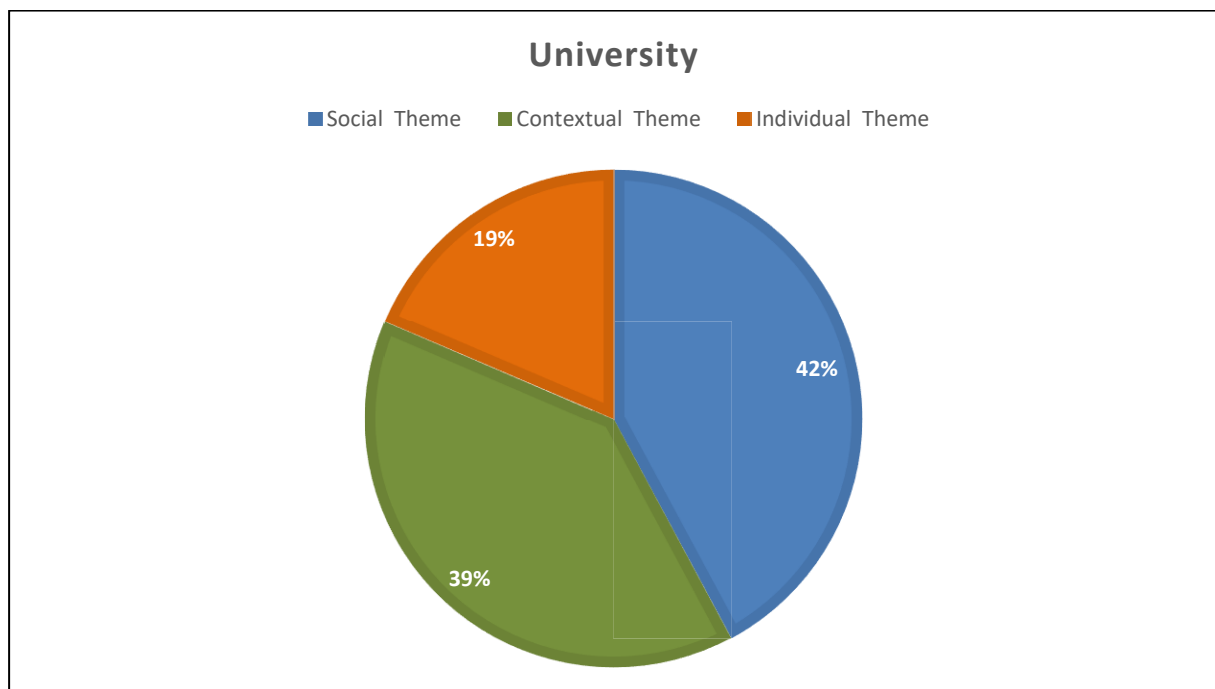


Figure 17 Distribution of the experiences and reasons in the university according to the themes.

Always

Most of the graduate students and postdoctoral researchers (80%), mentioned experiences and reasons that were not associated with a specific period, but they described as having "always" been present in their lives. The majority of the reasons belonged to the individual theme (57%, $f = 8$), and the rest to the social theme (43%, $f = 6$) (Figure 18). The individual reasons were related to participants' personal motivational beliefs and included goals, self-efficacy beliefs

and personal interests. One example was provided by Joseph, who was always interested in “understanding how things work, so breaking down processes and understanding individual components”. Related to social factors, Melissa mentioned the role of her mother as a definer that she considered has always been present: “so I guess, my mom, has always like supported me in that sense”.

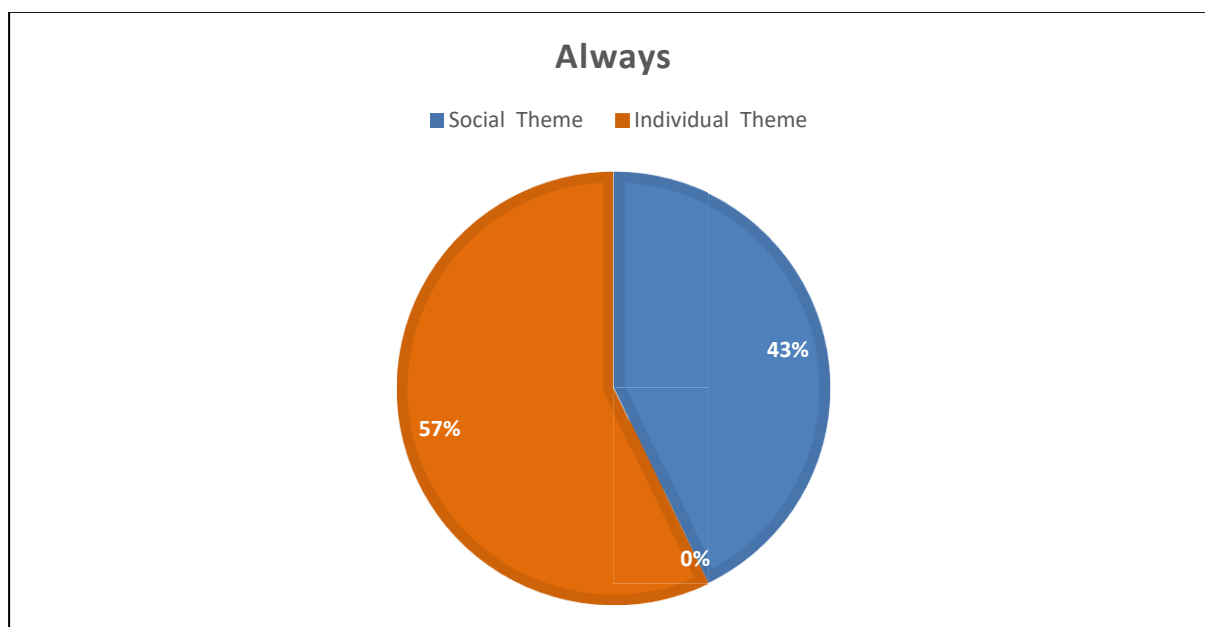


Figure 18 Distribution of experiences and reasons that were described as always present by the graduate students and postdoctoral researchers according to the themes.

5.3 RQ 3. What type of interest profiles can be found to lead to the science career path?

5.3.1 Kate, Lucas, Clara and Amanda: From the Garden to the Lab.

The science career paths of Lucas, Amanda, Clara and Kate have been defined by their interest in nature which was supported during different phases of their lives (Figure 19). They recalled outdoor experiences such as traveling, playing outdoors or being scouts in their childhood, and knowledge about problems related to nature at different phases and for different reasons (reading, class content, etc.). They also had the opportunity to discuss these topics with different people. Some of them had role models who were mostly teachers and professors in high school and university, but also famous scientists and colleagues. The summary of their paths is presented below.

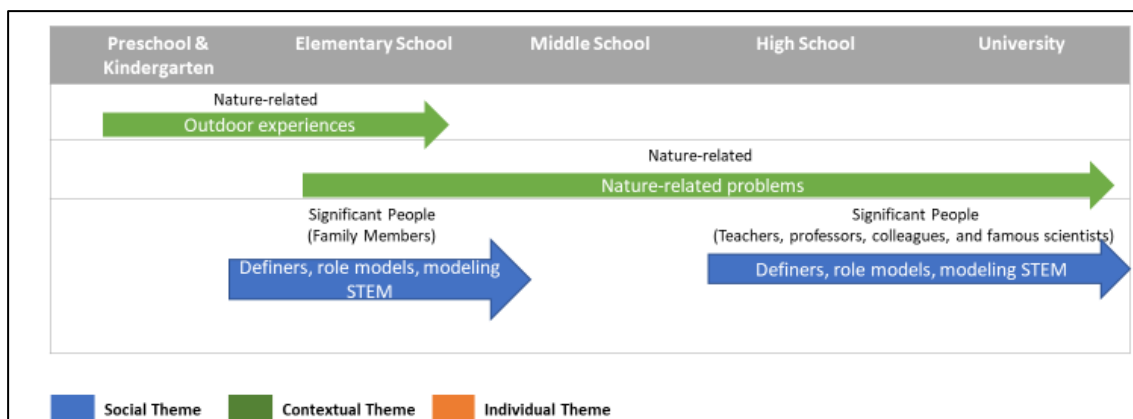


Figure 19 Representation of the similarities among profiles of Kate, Lucas, Clara and Amanda.

During the years related to preschool and kindergarten, Amanda used to collect rocks. The following years (elementary school) she travelled with her parents to geoparks, which made her be in contact with nature. She started to read magazines and watch TV programs about topics related to nature. This gave her the opportunity to discuss with her father about nature-related problems. During her high school years, she looked up to her geography teacher as a role model, because “she was a really good teacher” (Amanda) who “taught in an interesting way” (Amanda), and who also provided feedback. Then, Amanda decided to carry on a science career path because of her geography teacher and her interest in nature. During her bachelor’s degree, the university allowed her to select some courses by herself, so she could study topics based on her interests. She also found a role model in a professor who was also her thesis supervisor, as he was “enthusiastic about science” (Amanda).

Clara.

During the years of preschool and kindergarten, Clara used to play outside and observe ants. During the years of elementary school, she became a scout, which made her be in touch with nature and learn about nature-related issues. She also had science-related toys, like chemistry sets. During these years, she was interested in reading a book about famous scientists, and she grew up looking up to them as role models. Clara also started to watch TV shows of science for kids. During middle school, she realized she was good in chemistry and biology, and she also became an activist for Greenpeace (including her high school years). Also, in high school she had the goal to work for Greenpeace, so she decided to choose a science career path with the help of her mother, who was defining some careers for her. During her years in university, she had the opportunity to choose some of the courses and developed interested in geology. She

also did some practical work in the lab. Her professors were modeling STEM, and also role model, due to their “passion”. Clara has always admired a famous activist called Jane Goodall. Also, Clara has always been in contact with science due to the job of her dad, who is a doctor.

Lucas

Lucas used to play with soil and worms during his early years. During his years in elementary school, he did outdoor activities such as bird watching, and with his parents he used to hike, which made him “interested in what’s going on with the environment” (Lucas). He also became a scout. Furthermore, he lived in a city with environmental problems. He also started to watch TV shows about science. During high-school, he mentioned that he “did the best in science” which made strongly supported his decision to study something related to it. Moreover, he was aware about nature-related problems that involved animals. He also enjoyed asking questions to his teachers to discuss about science, and his teachers, as Lucas mentioned “also liked it”. During the university, he had the opportunity to do a project that involved taking samples from a river, which made him more aware of the current problems in nature.

Kate

Kate recalled that during her elementary school years, she and her parents went fishing and to the forest. She also was taught about plants and animals through her parents, even if they were not working in a science-related field. Kate mentioned she has always been an “animal lover” and interested in “solving problems” as she wanted to “leave [her] name on history”. During her years in high school, she got “interest” and “worried”, when in one of the classes they learned about environmental issues, which made her read by herself more about the topic followed by discussions with some schoolmates. She realized she wanted to do “something practical related to nature” and that biology was a way to achieve this. During her years in university, she had the opportunity to do practical things such as research and experimenting. She had a professor who was a role model for her as well as a definer, because she had the opportunity to talk him about science and nature. She also talked about these topics with some colleagues.

5.3.2 Mariam: A Background Interest in Nature was Stimulated in University.

Mariam had a background interest in nature similar to the previous participants, however, her career path was different. She liked the biology class in high school, but she was not sure about

which degree to pursue. She decided to study the same majors as her friend because it “sounded interesting” (Mariam). Mariam’s interest was mostly developed in university, due to her self-efficacy beliefs, the content of some classes, and the role of significant people. The profile of Mariam followed by a summary of her career path in science is shown below (Figure 20).

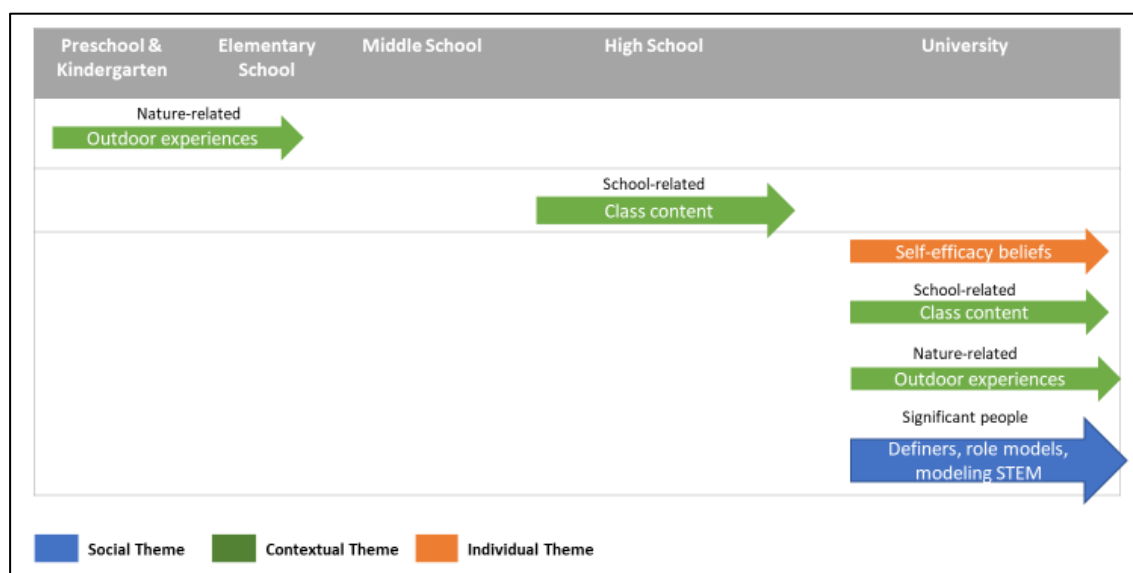


Figure 20 Representation of the profile of Mariam.

Mariam

During her years related to kindergarten and preschool, she liked to play outdoors and collect feathers. Mariam used to go hiking with her parents. She also did other outdoor activities such as birdwatching. In high school, she had a good biology teacher and she described the content of the class as “interesting”. By the time she had to decide for a bachelor’s degree, she was not sure about her interests and decided to take the same 2 majors that her friend. Mariam’s friend explained to her the things that she/he was doing and that “sounded interesting” for Mariam. She had one class related to biochemistry, that increased her self-efficacy beliefs, as she mentioned “I was good in biochemistry”. That made her decide to study biochemistry. Mariam also explained how her interest was stimulated:

“I suppose I always had like a background interest, just like I suppose a lot of people that have an interest in nature, and birdwatching, and probably stemmed from when I started doing biochemistry, and I was good at it” (Mariam)

Some of the classes made her more interested, as they were very practical, and she had the opportunity to work in the lab. During these years, she had the opportunity to visit natural parks due to her boyfriend, and as she described: “that promoted [her] interest”. She also mentioned that some of the content in the lectures was important for her, such as learning about Malaria. She also mentioned that her thesis supervisor and his wife were really important for her:

“They'd always point my spirits when I'd read something, like ‘if you're talking about that..., what you want to say?... It sounds good’. They always keep my interest and that's what I think always wanted to do something that would bring back what I got from it” (Mariam)

Mariam looked up to her husband as a role model, due to his work that is also related to her field. Mariam thought of being a researcher, but she has changed her decision in some occasions for different reasons, and she decided to do a second degree in science.

5.3.3 Joseph, Melissa and Patricia: Significant People and Topics.

Joseph, Melissa and Patricia were all in contact with science during their childhood due to their families, although in different ways (role models, modelling STEM, and as definers). During their middle school or high school years, they were triggered by content related to science in class that influenced the decision to pursue a specific degree in science. All of them had the opportunity to do practical things during their bachelor's degree, including research. They all mentioned that one or various professors were supportive and functioned as role models. Interestingly, during their higher education, all of them had the opportunity to meet and get inspired by famous scientists or researchers, including a Nobel Laureate. The similarities among their profiles is shown in Figure 21. The summaries of their science career path descriptions are presented below.

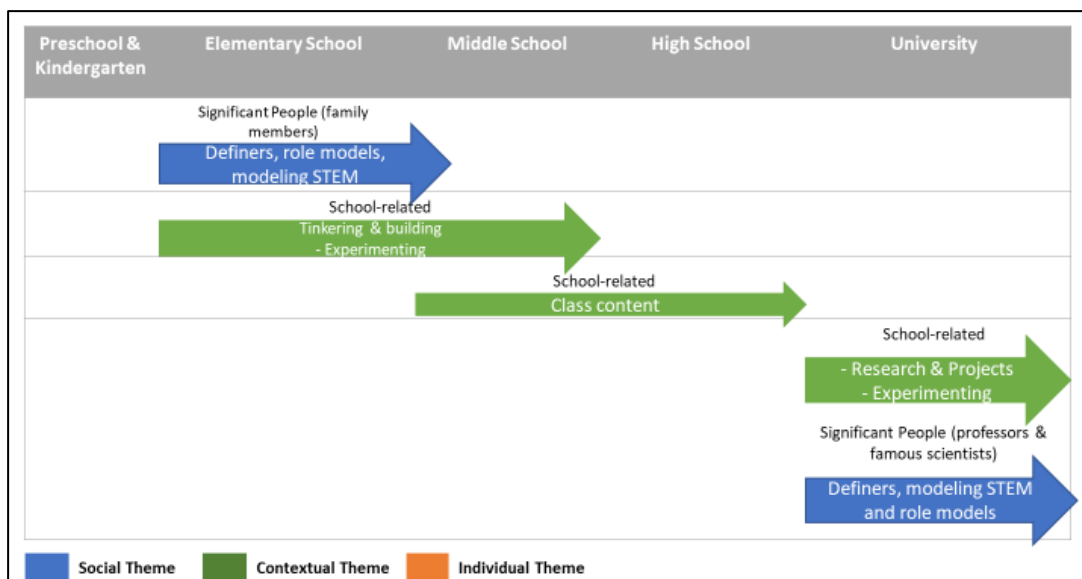


Figure 21 Representation of the similarities among the profiles of Joseph, Melissa and Patricia.

Joseph.

Joseph has always admired his father, who is also working in a STEM career, same as his grandfather. He had the opportunity to see the things his dad and grandfather were doing. During a class in elementary school, he had the opportunity of growing crystals and other experiments. He also watched a TV show that “aimed to introduce kids to the science process” (Joseph) and made science “fun” and “tangible”. During his years in high school he decided to take courses in chemistry, because as he mentioned: “for some reason I decided I liked chemistry”. During these courses they were experimenting in the laboratory, which allowed him to relate things from “a chalkboard...into actual experiments” (Joseph). He mentioned that “something about the teacher was very good” but that he was “amazed” by one of the contents of the class, the periodic table, because for him “it’s very fascinating or it’s very cool that you can organize all the elements”. He selected a science degree based on his experiences in the chemistry classes and that he always wanted to work in something similar to his father’s field. During the university, his goal was “do groundbreaking research”. He looked up to some professors as role models, due to the way they taught and because some of them were famous researchers who were authors of the books Joseph read for the courses. He also recalled that in one of the courses he had to work in a project in which it was needed to apply all the theory he learned. During these years in university, he had the opportunity to do more research and also discuss about his interests and options with a professor who “pushed him into this path” (selection of a PhD program). He also mentioned that his supervisor has been a definer for him.

Joseph pointed out that he had always enjoyed “understanding how things work, processes and so on” (Joseph).

Melissa.

During her childhood, Melissa played a memory game created by her mother to learn the classification of plants according to their species and genus. She also participated in the yearly science fair in her elementary school building different models. One year she built “a magnetic line to make a castle”. She mentioned that during these activities she was supported by her teachers and parents, who helped her to define some ideas and understand them, especially because in her house they “always had this thing that you need to understand what you are doing” (Melissa). During middle school, she was triggered by one of the topics of the class “genetic engineering” because as she pointed out “[she] wanted to know more about something which is hardly taught in 12th grade textbooks”. She also mentioned she was discussing about “how nanotechnology would be used for face creams” with either her uncle or father, and she realized she needed more knowledge to discuss. At the end of her high school studies, Melissa decided to study something related to science to be “academic valuable”. At the university, the topic of “cell division” got her attention and made her interested in knowing more about “where we came from” and the “unknown things” in science. During some classes she and her classmates had the opportunity to do experiments and to come up with their own ideas and projects, to also teach younger students about science. She also looked up to her boyfriend due to his way of studying. In her master’s degree, the curricula were flexible, and one professor supported her learning process and helped her to develop scientific skills, which made it possible for Melissa to start her own projects. She also pointed out that the experience of being in one lecture of a Nobel Laureate was important for her, as “he would teach a very complex thing in such a basic manner” (Melissa) and he was also a “humble” person.

Patricia

During her childhood, the sisters of Patricia were modeling STEM for her, as they were doing a bachelor’s in science. She had the opportunity to observe some of the things that her sisters did at home. She also liked to watch science talk shows that presented “science models”. During her middle school, she participated in science fairs, preparing charts and diagrams. In high school, she was triggered when in class they studied the topics of DNA as “it sounded like an interesting topic” (Patricia), human anatomy because “it was also interesting how the body is communicating” (Patricia), and the plants and their kingdoms as it was “interesting to see the

symmetry in nature” (Patricia). She had the opportunity to choose a specialization in high school. She chose biology, especially due to the topic of DNA. Then, she decided to study a degree in biotechnology, because “DNA and it was a hot career in the moment” (Patricia). From the early stages of her higher education studies, she wanted to do research, which was supported by her professor who gave her the opportunity to join some projects and who gave feedback to her. She also had the opportunity to do a small project with a colleague, that was helpful for understanding more about the process of doing research. The experiments in class were also important for Patricia, as they were helpful for “visualizing things”, together with working in special labs for biotechnology. She also admired a professor who was knowledgeable and skillful in her eyes. During her years in university she had the opportunity to attend conferences, and “get inspired by big scientists” (Patricia).

5.3.4 John and Edward: An Early Interest in Science.

John and Edward had an early interest in science that was supported and fostered by their parents in their childhood. During their years in elementary school, the practical activities they did at school and at home were related to science, which strengthened their interest. Also, both were reading books related to science. Their years in middle school or high school helped them to confirm that they wanted to study something related to science. For example, John was selected for a top-level project in science while Edward received good grades in science-related subjects. In university, they had hands-on experiences through experiments, and doing research. Figure 22 represents the similarities among their profiles.

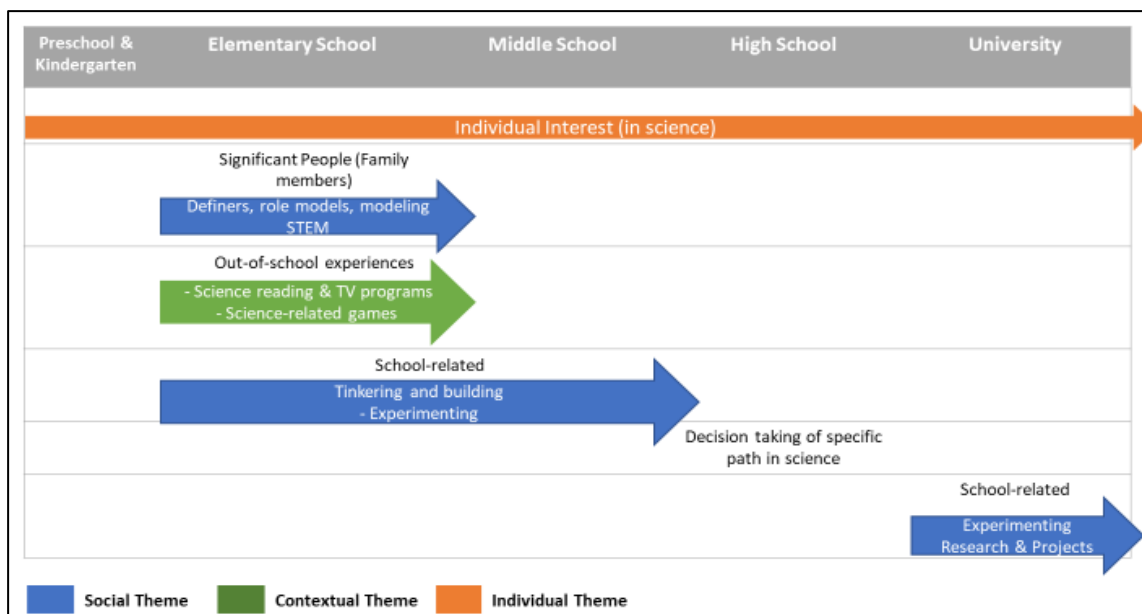


Figure 22 Representation of the similarities among the profiles of John and Edward.

John

John has described himself as “curious and interested in science topics” since he was really young. During his childhood, John was influenced by his grandmother and parents to ask questions and seek for more information. He was also reading books provided by his parents that made him see “science part of the surrounding” (John) and he watched TV shows that as described by him, “encouraged kids to do experiments and see what was happening outside”. Both things made John more interested in science topics, and he already knew he wanted to study something related to science during his elementary school years. In one of the classes, a teacher asked him and his classmates “What do you want to be?” a classmate said “scientist”, which made John realize that scientist was a profession. During these years, he had teachers who were modeling science experiments, and he also had the opportunity to do experiments in class. He also did things at home by himself such as disassembling a car to understand how it works. During his years in a middle school, that was famous for encouraging students to have hands-on experiences, he had the opportunity to build and tinker at class, and as he pointed out “that made my interest in science strong and more deep [sic]”. In high school, John was selected among his classmates to participate in a science project that was “top level” as described by him. He also went to a science camp which helped him to know more about the option of studies. After that camp, he decided for the specific degree he wanted to pursue and for the college he wanted to go to. During his years in university, he had the opportunity to do some

practical work, and also decided to continue in research “because of more freedom and more time doing science-related stuff”.

Edward

Edward described how his interest in science began: “I think when I was very young, I have the idea that I want to become a scientist...I think more or less I already have this idea to become to work in science or nature science”. During his childhood he had the opportunity to meet some doctors, and he saw them as a role model. His parents provided him with books and science-related toys, such as a physics’ kit with electronic components that he enjoyed. He also read books about the galaxies or human anatomy, which were his interests in that moment. In his classes at elementary school, he and his classmates had the opportunity of doing experiments, something that he also tried to do at home. He also recalled that in one of the classes, he had the opportunity to build a motor by himself. In high school, he did well in mathematics and physics, and by that time his “interest in science is for sure” (Edward), so he decided to continue in a specific science “track”. In university, he had the opportunity to select which courses to take due to the “freedom environment” of the university. He also had practical experiences in the lab and then decided to continue his higher education studies, also with the advice of some colleagues.

5.4 Summary of the Main Findings

5.4.1 RQ 1. What type of interest-related reasons and experiences did the participants describe as influencing on their science career path development?

The reasons and experiences that influenced the career path of science graduate students and postdoctoral researchers were classified under the themes: social, contextual, and individual.

Social Theme. Most of the significant people influenced the participants by being role models (39%), followed by definers (36%), and the rest were modeling STEM (25%). Most of the significant people were teachers and professors, followed by family members, classmates and colleagues, and others (famous scientists, sweethearts, etc.).

Contextual Theme. The contextual theme included mostly school experiences, followed by nature-related experiences and the rest included out-of-school experiences. The experiences associated with the school included: interest in class content and materials, tinkering and

building, experimenting, participating in projects and research, and the opportunity to choose courses by oneself (flexible curricula). In the experiences related to nature, the participants described outdoor activities (e.g. hiking, playing with insects, fishing, etc.) and knowledge about problems associated with nature. The described out-of-school experiences were science reading (e.g. magazines and books), watching science TV shows, and playing science-related games.

Individual Theme. It was also found that self-efficacy beliefs, the individual interest, and the goals of the graduate students and postdoctoral researchers influenced their pathways. For some of them, their self-efficacy beliefs were based on their performance in science classes, and which influenced their decision of pursuing a degree in the same field. Some of them had goals related to science or goals that they thought were possible to achieve through a science career path, such as work with nature.

5.4.2 RQ2. How the different types of interest-related reasons and experiences were situated in the different phases of their science career path?

Preschool and kindergarten. Most of the interest-related experiences and reasons (83%) were associated with outdoor experiences and science reading (contextual theme) and 17% with significant people (social theme).

Elementary school. More than half of the interest-related experiences (57%) were related to the context, most of them associated with school, followed by out-of-school and nature related experiences. A third (33%) corresponded to significant people (social theme), especially family members and teachers who were modeling STEM, definers and role models. Only a 10% was attributed to the individual theme, especially the category of individual interests.

Middle school. Half of the experiences were related to the context, especially out-of-school and school-related experiences. Approximately one third (33%) were associated with individual reasons mentioned, including self-efficacy beliefs and individual interests. Only 17% were related to significant people (social theme) who were definers.

High school. More than half of the experiences were related to the contextual theme (55%), especially nature-related problems and school-related experiences such as interest for a topic (class content), experimenting, research and projects, and decision making. Individual reasons represented a 28%, including all the categories (goals, self-efficacy beliefs, and individual

interests). Only 17% was associated with the social theme, that especially included teachers as role models.

University. The social theme represented 42%, especially professors who were role models, modeling STEM and definers. The contextual theme obtained 39% and was mostly associated with school-related experiences such as experimenting and doing research and projects, and nature-related experiences. Only 19% was related to the individual theme.

Always: the individual theme represented 57%, including individual interests and goals. The rest was associated with the social theme (43%), especially with significant people who were role models.

Many of experiences and reasons were situated in university, followed by elementary school, high school, always, preschool and kindergarten, and the least experiences were situated in middle school.

5.4.3 RQ3 What type of interest profiles can be found to lead to the science career path?

Four different interest profiles were found to lead to a science career pathway.

The first path was associated with an interest in nature that was fostered in childhood through outdoor experiences that were mostly provided by their family members. This was combined with the knowledge of environmental or nature-related problems from elementary school onwards. The graduate students and postdoctoral researchers had the opportunity to discuss about nature with significant people, especially with teachers and professors, and colleagues from high school onwards.

The second path was to a certain degree related to the first, because the participant had a background interest in nature due to outdoor experiences in her childhood. However, her interest in science was stimulated in university due to self-efficacy beliefs, when she realized she was good in one of the subjects. She also got interested in some of the class contents and had the support of significant people who were modeling STEM, role models and definers from university onwards.

The third path was associated with significant people and interest in a specific class content in high school. During the childhood of the participants, they were involved in science through family members, who were modeling STEM, definers and role models. They also were

tinkering and experimenting in elementary and middle school. All of them were triggered by a science class content in high school that influenced their decision of studying science. During university, they did practical work (experimenting and research) and also got inspired by professors and famous scientists.

In the fourth path, the participants had an early interest in science. This interest was supported and fostered during elementary school by significant people (especially family), out-of- school experiences such as science reading and science TV shows. They were also tinkering and experimenting in their classes in elementary and middle school. The experiences in high school just reaffirmed their interest in science and they decided the specific path to take. In university, the participants had the opportunity to do research and experiments.

6 Discussion

6.1 RQ 1. What type of interest-related reasons and experiences did the participants describe as influencing on their science career path development?

Graduate students and postdoctoral researchers described social, contextual and individual interest-related reasons and experiences as influencing on their science career path development. In the case of social reasons and experiences, the findings indicate that the most influential people are family members, teachers and professors, and to a lesser extent, famous scientists. This is aligned with results of previous studies in which the people who the participants knew in person had a significant influence on their career choices (Jones et al., 2011; Sjaastad, 2012). Earlier research has especially indicated parents and teachers as significant for the learners as they can be role models, provide support and experiences that foster interest in science (Ainley & Ainley, 2015; Jones et al., 2011; Sjaastad, 2012).

One way in which the significant people influenced the graduate students and postdoctoral researchers in this study was as role models. A role model can display what a scientist is, and that can help the students to understand the work they do, and the abilities and characteristics that someone in the science field has. Earlier research has also found an indication of the importance of a role model for displaying the characteristics of a scientist. Lyons and Quinn (2010) found that one of the reasons for not choosing science subjects was that students were not able to imagine themselves as scientists.

Another way in which people influenced the participants of this study was through the support and feedback provided, as well as the opportunity to discuss science topics with them. The support had value for the self-efficacy beliefs of the participants (Sjaastad, 2012), as they could improve their skills and increase their knowledge through these interactions, and later evaluate and discuss with these significant people the possibilities and options of studying a science degree. However, earlier research has found that interactions with others can be perceived in a different way. For example, Holmegaard, Ulriksen, and Madsen (2014) interviewed students about their higher education options. Their findings indicated that social networks provided experiences and support, but participants decided not to use these available resources since they considered that the selection of a career is an individual decision based on their own interests. Therefore, it is important to make the learners aware of how their own interests and opinions are taken into consideration when they receive support.

In the case of the experiences and reasons that were related to different contexts, they were classified into school-related experiences, nature-related experiences and out-of-school related experiences. The findings in this study indicated that active learning experiences in school such as tinkering and building, experimenting, developing projects and research were influencing participants' interest, which was also aligned with the results of previous studies (Jones et al., 2011; Maltese & Tai, 2010; Maltese et al., 2014). The opportunity to be actively involved in these types of activities can be rewarding and related with positive feelings when the learners see the results of their projects or experiments. Furthermore, while participating in these activities, the learners are practicing and developing skills that are associated with science (Jones et al., 2011). In addition, Tytler et al. (2008) found that the lack of science content is one of the problems that prevents the development of interest in this field. In the present study, the graduate students and postdoctoral researchers mentioned the importance of science content they learned in school. In some cases, this content was relevant because it triggered their interest by its novelty (Hidi & Renninger, 2006; Renninger et al., 2018), but also due the connection found in it with their previous interests. In general, research has repeatedly shown the importance of classroom context for motivation and interest, especially the design of learning tasks and the role of teachers (Aeschlimann et al., 2016; Ames, 1992; Anderhag, Hamza, & Wickman, 2015). To foster motivation and interest, the learning tasks need to be meaningful and challenging for the students, as well as help them to develop different skills (Ames, 1992). Teachers need to focus on supporting students during the tasks, and providing feedback (Ames, 1992; Anderhag et al., 2015). Especially for science classes, implementing a variety of well-designed learning activities that are connected to real-life contexts, providing information about the options in STEM careers, and giving individual support to the students are essential factors for supporting students' motivation and interest (Aeschlimann et al., 2016).

Nature fostered interest through outdoor experiences and knowledge about currently existing environmental problems. These types of nature-related experiences can be a bridge connecting the students with applied science in the real world, which is in agreement with results of previous studies (Crowley et al., 2015; Jones et al., 2011). For example, in the findings of Bong et al. (2015), field trips and excursions were identified to establish a connection with science. Another way in which the graduate students and postdoctoral researchers connected science with their environment and perceive it as something tangible, was throughout out-of-school experiences, including science reading, watching TV and games. These activities were done mostly voluntarily which indicates a predisposition to reengage in science content; however,

some were promoted by their social network. In the study of Dabney et al. (2012), the participants who read or watched science-content reported more interest in studying a STEM related degree in comparison with the ones who did not participate in these types of activities.

Individual aspects were the least mentioned among the three themes (individual, social and contextual). The self-efficacy beliefs of the graduate students and postdoctoral researchers were reinforced through their performance in class and their grades. Also, they had individual interests related to science developed throughout different experiences that sometimes were used to establish goals. Self-efficacy and establishment of goals are associated with the development of interest (Ainley et al., 2002; Bong et al., 2015; Schunk & DiBenedetto, 2016). Previous studies have found a strong association between self-efficacy and interest in science, with higher possibilities to enroll in a STEM career path (Bong et al., 2015; Sahin et al., 2017). However, these individual aspects can be influenced by the interpretation of the student, that is shaped by the interaction with the context and the social network (Schunk & DiBenedetto, 2016). The low number of interest-related experiences and reasons related to individual aspects, can be the result of the participants' unawareness of their individual interests, which is a characteristic of interest (Renninger & Pozos-Brewer, 2015; Renninger & Bachrach, 2015). It can also be related to the value that participants gave to their own performance in science activities and how they associated it with their self-efficacy (Schunk & DiBenedetto, 2016).

6.2 RQ 2. How the different types of interest-related reasons and experiences were situated in the different phases of their science career path?

Most of the interest-related experiences described by the science graduate students and postdoctoral researchers were situated in university, followed by elementary school, high school, preschool, and finally middle school. The interest-related experiences and reasons associated with preschool and kindergarten in the present study were few. In contrast, the study of Maltese and Tai (2010) indicated that early childhood was relevant to begin the development of interest in science. The interest-related experiences in preschool and kindergarten in the present study were related to the context, specifically playing outdoors (nature-related) and science reading or watching TV (out-of-school). Crowley et al. (2015) conducted a study in which scientists and engineers were interviewed, and found that in some of the cases, the first interaction that their participants had with science was through nature.

During the years in elementary school, most of the interest-related experiences and reasons described by the participants were associated with school, especially class content, experimenting, tinkering and building. Since previous studies have also found that these years are relevant for triggering and developing interest in science (Crowley et al., 2015; Maltese & Tai, 2010, 2011; Maltese et al., 2014), and according to this study the school played an important role, then, active learning activities that foster interest in science should be promoted in the classroom. However, in the study of Crowley et al (2015) the participants did not report school-related experiences that triggered or developed their interest in science. The results of the present study indicate that during the years in elementary school, some of the participants had the support of family members and teachers who influenced them in different ways, which is similar to the findings reported in a previous study (Dabney et al., 2013).

Dabney et al., (2012) found that interest in science and mathematics during middle school was associated with a higher possibility of choosing a STEM career. However, the graduate students and postdoctoral researchers in this study reported few interest-related reasons and experiences in this phase. The majority of the interest-related reasons and experiences in high school was associated with the context, followed by individual and social reasons. The experiences related to school context included the interest in class content, and in some cases the opportunity provided by the school to select some courses based on their own interests. In the study of Maltese and Tai (2011) the findings indicated that course selection in high school was a key factors to pursue and obtain a degree in STEM. If the students are developing an interest in science and have the opportunity to enroll in courses related to their specific area of interest, they have more opportunities to develop skills and acquire knowledge in the respective area (Jones et al., 2011), which can also increase their interest and self-efficacy beliefs.

Finally, during the years in university, the graduate students and postdoctoral researchers mentioned the importance of their social networks and school-related experiences. Their professors influenced them as role models, but also provided support and experiences related to science. This can also be associated with a high developed individual interest in science, as people tend to look for opportunities to do activities in their area of interest, but also be surrounded by people who inspire them and provide support (Crowley et al., 2015).

6.3 RQ 3. What type of interest profiles can be found to lead to the science career path?

Four different interest profiles were found to lead into a science career path in which the interest was supported through interactions with the environment (Ainley, 2007; Hidi & Renninger, 2006). In the first profile (Kate, Lucas, Clara and Amanda: From the Garden to the Lab), the graduate students and postdoctoral researchers manifested an initial interest in nature during their childhood which further developed with the support of their social network in different phases. Their family members provided experiences related to nature that helped them to reengage in the area. Similarly, the findings of Crowley et al (2015) indicated that an early interest in science is also associated with experiences in which family members were involved. In the first profile, Kate, Lucas, Clara and Amanda were either seeking more knowledge or already knowing through their contexts about the problems related with nature, from elementary school to university. That helped to maintain their interest during these periods and stored more knowledge and understand the value of nature in the world (Hidi & Renninger, 2006; Renninger & Pozos-Brewer, 2015). Therefore, during their years in university, they seemed to have an individual well-developed interest, as they were more independents, in terms of selecting their own courses, but also seeking and enrolling in projects to gain more knowledge and practical experiences in the field (Crowley et al., 2015; Hidi & Renninger, 2006). Moreover, they found role models in their professors and teachers, and opportunities to discuss relevant topics with them. In contrast, in the second profile (Mariam: A Background Interest in Nature was Stimulated in University) an initial interest in nature arose during childhood, but it was not well-developed before starting university, due to the lack of external support that prevented keeping the interest (Hidi & Renninger, 2006). The interest was developed through the combination of self-efficacy beliefs, interest in class content, active learning experiences in university, outdoor experiences and the support of the social network. However, the interest in science is still in development, as the participant has changed the specific branch of science in her studies. The second profile is a clear example that triggering and developing interest can happen at any phase or age and usually needs external support (Ainley, 2007; Hidi & Renninger, 2006; Renninger et al., 1992; Renninger et al., 2018).

The third interest profile (Joseph, Melissa and Patricia: Significant People and Topics) is similar to the first one, as in both cases graduate students and postdoctoral researchers had support of family members during elementary school. However, they also had the support of active learning experiences in elementary and middle school, contrasting to previously described profiles and findings (e.g. Crowley et al., 2015). The graduate students and postdoctoral

researchers in this profile had a general interest in science fostered in their childhood. Following elementary school, class content in middle and high school stimulated their interest toward a specific branch of science. During university, they were involved in practical activities such as experimenting and doing research with the support of their professors. The graduate students and postdoctoral researchers in this profile became inspired by their professors and also by famous scientists who showed characteristics, behaviors and achievements which they imagine to have in their science careers as well (Sjaastad, 2012; Woelfel & Haller, 1971).

In the fourth interest profile (John and Edward: An Early Interest in Science), the graduate students and postdoctoral researchers manifested an individual interest in science that had always been present in their lives. This interest was supported by significant people (family members) and school-related experiences in their childhood, similar to the third profile. However, they described the relevance of the out-of-school experiences, in which they read or watched TV of science-related content. They also played science games at home, that sometimes were inspired by the activities done at school, which can be associated with a well-developed interest, as they independently reengaged in science content (Crowley et al., 2015; Hidi & Renninger, 2006). Experiences and reasons associated with high school just helped them to select the specific path, similar to the third profile. In university, they were not aware or even actively looking for support or inspiration from their social network, like in the third profile. They were more focused on doing practical activities such as experiments and research that helped them to decide how to continue their science career paths.

7 Conclusions

The present study aimed to explore the retrospective descriptions of the reasons and experiences that have influenced the development of interest in science in graduate students and postdoctoral researchers. The first main finding of this study indicates that social, contextual and individual interest-related experiences and reasons were significant for their science career pathways, as previous studies have suggested (Crowley et al., 2015; Dabney et al., 2013, 2012; Fredricks, 2011; Jones et al., 2011; Maltese & Tai, 2010, 2011; Maltese et al., 2014). In the case of contextual theme, active learning experiences in school triggered and developed the interest in science (Jones et al., 2011; Maltese & Tai, 2010; Maltese et al., 2014) and nature-related experiences were important to connect science with the participants (Crowley et al., 2015; Jones et al., 2011). Similarities were found with the study of Dabney et al (2012), who also identified science reading and TV watching as out-of-school experiences associated with interest in studying a STEM degree. In the social theme, family members and teachers and professors were influencing especially as role models and definers the interest towards science (Jones et al., 2011; Sjaastad, 2012). The individual theme was the least mentioned, but it was significant as the experiences and reasons related to their individual interests, goals and self-efficacy beliefs were positively linked with science. Previous researchers have found a positive correlation between self-efficacy and the development of individual interest in STEM (Bong et al., 2015).

The second main finding indicates that most of the interest-related experiences and reasons described were situated in university, followed by high school and elementary school. During these phases, the support from significant people (family members, teachers and professors) and school-related experiences was relevant. In high school and university, individual reasons and experiences were also important, as the participants developed self-efficacy beliefs based on their performance (Schunk & DiBenedetto, 2016) in science-related activities and also established goals. Few experiences were situated in preschool and middle school, which is contrasting with the findings of Dabney et al (2012), who found experiences in middle school to be significant.

The third main finding of this study shows four different interest profiles that lead to a science career path. In the four profiles the interaction of the interest-related experiences and reasons, especially the ones related to the social support and the context were essential for the well-developed interest in science. This is aligned with previous studies that have found that the

combination of positive social, individual and contextual experiences and reasons increases the possibilities to develop interest in a specific area (Eccles & Gootman, 2002; Fredricks, 2011). Furthermore, in three of the profiles the role of family members, especially during childhood was significant as they provided experiences, objects or materials that either triggered or helped to the development of interest in science (Ainley & Ainley, 2015). Moreover, in also three profiles the positive interactions and the support provided by teachers and professors were essential for the participants (Fredricks, 2011) who looked up to some of their professors as role models. Nevertheless, in one of the profiles also famous scientists were perceived as role models. However, most of the significant people that influenced the interest in the four profiles were those with whom the graduate students and postdoctoral researchers had direct interactions, as a previous study indicated (Sjaastad, 2012). In most of the profiles, a general interest in science began in childhood (Maltese & Tai, 2010) and was well-supported in different ways that led to the selection of a science career after high school. However, in one of the profiles is also clear that interest can be triggered and developed regardless of the educational phase and age of the learner (Renninger et al., 2018) when he or she is externally supported.

7.1 Implications

The results of the present study provide information about the types of interest-related experiences and reasons that influenced the science career path of the participants. Moreover, these experiences were situated in the different phases in which they occurred to find different profiles that lead to a science career. The findings presented have implications for family members, teachers and professors, and schools that want to promote and support the interest of their students in science.

The results show the relevance of the family, especially during childhood, as they can provide science-related experiences that trigger interest in the area. Family members, especially parents can help to the development of interest through nature-related experiences, but can also provide science-related toys or materials (Ainley & Ainley, 2015) to stimulate the curiosity of the children for science topics. Schools can also provide experiences in nature and relate them to science through relevant topics for the society.

Some of the participants recalled the active learning experiences in school that either triggered or supported their interest. Providing hands-on experiences that involve the use of objects and

materials used in a laboratory can help the students to understand more about the work of a scientist, and to develop skills that are useful in this field. In addition, it can help to see science as real and tangible, and applicable in real settings (Sjaastad, 2012).

Professors and teachers were relevant for the graduate students and postdoctoral researchers, as they provided support, science-related experiences, but also as role models. Teachers and professors can be essential in the development of interest in science by providing engaging activities related to science, but also giving feedback to the students and make them reflect about their science-related skills. Furthermore, it is important for teachers and professors to show positive attitudes toward science, as for the participants in this study the enthusiasm and passion of their teachers was relevant.

The findings of this study indicate that the combination of different sources of external support was essential for the development of interest in science. Therefore, the collaboration between schools, teachers and families can be relevant for supporting the interest in science. Science-related activities promoted by the school that involve the participation of families can be a way to foster the interest of the students, but also can help to make the parents aware of the relevance of this field.

7.2 Limitations and Future Research

The present study has some limitations. Firstly, English is not the native language of some of the participants, which made it difficult for some of them to find the words to describe their experiences. However, they were giving more details about the interest-related experience to make their descriptions more accurate. Secondly, the graduate students and postdoctoral researchers were asked to recall previous experiences, of which some of them happened a long time ago. The descriptions of these experiences may be altered in the memory and therefore differ from the original situations (Brewer, 1994). However, a timeline was used as a prompt to retrieve the memories more accurately and to help them to organize the memories into the right phase of their science career path. Moreover, there are few studies that have analyzed the development of interest in science from the perspective of people who are already in a science career (Jones et al., 2011), which is beneficial to understand the type of interest-related experiences and support that can lead to a long-term and well-developed interest in science. Thirdly, the small size of the sample, limits the results from being generalized to a larger population. However, the small sample size allowed the researcher to make an in-depth analysis

of the interest profiles of the postdoctoral researchers and graduate students to find patterns among their science career pathways.

The results presented in this qualitative and exploratory study provides information about the different profiles that lead to a science career path from the perspective of graduate students and postdoctoral researchers. Future research requires a larger sample size to increase the possibility to detect more patterns and interest-related experiences that can lead to a science career path, including consideration of demographic variables. In addition, as this study focused on the area of science, future research should explore the interest-related experiences and the patterns in the other areas of STEM. Moreover, how self-efficacy beliefs related to science are developed and how they can be supported to increase the interest in science is an important question of future research. Considering that women are still underrepresented in the STEM fields (Aeschlimann et al., 2016; UNESCO, 2017), further research is needed to explore the interest profiles of female scientists, with the focus on analyzing the key educational phases and the types of interested-related experiences and reasons that influenced their science career pathways.

8 Evaluation

8.1 Validity and Reliability

Eisenhart and Howe (1992) named five standards to ensure the validity of educational research. The first standard is related to the alignment between the research questions, the data collection procedure and the analysis method (Eisenhart & Howe, 1992). From the beginning of the study, it was aimed to explore from a qualitative perspective the experiences described by the participants. Therefore, the aim and research questions were designed according to that purpose. Then, in-depth semi-structured interview was selected as data collection procedure, to gain a deep understanding of the experiences and reasons described by the participants as relevant (Creswell, 2012). Interview is a data collection procedure frequently used when the researcher aims to use content analysis method, like in this study (Drisko & Maschi, 2015). Content analysis helped to identify the meaning in the episodes described by the participants (Drisko & Maschi, 2015).

The second standard is related to the correct application of the data collection procedure and analysis technique to ensure its effectiveness (Eisenhart & Howe, 1992). An interview protocol was designed to guide the interviews. A pilot study was conducted to ensure the quality of the questions and to identify the potential flaws. The feedback of the interviewee was used to improve the interview protocol, including help of an experienced researcher. Related to the analysis technique, the coding scheme was developed through abductive reasoning that combines deductive and inductive reasoning. This was done to start the coding scheme with previous findings but enriching it with the data of the study. Moreover, the data was coded several times to ensure quality.

The third standard is related to the use of prior knowledge. To increase the credibility of a study, previous empirical findings and theories should be used as a base for comparing and arguing (Eisenhart & Howe, 1992). In the present study, the theory and previous studies mentioned in the theoretical framework were the base for developing the aim, research questions, data collection method, the coding scheme and to compare the results.

The fourth standard is related to the external and internal constraints (Eisenhart & Howe, 1992). External constraints are concerning the value of the research for educational purposes (Eisenhart & Howe, 1992). The present study addresses the development of interest in science from the perspective of science graduate students and postdoctoral researchers. It is based on the issues that governments and educational systems are facing, to generate and maintain interest in the field of STEM which is an essential field for the society (Ainley, 2007; OECD, 2006; Osborne & Dillon, 2008; Thisgaard & Makransky, 2017; UNESCO, 2017). These issues have been mostly researched from the perspective of students from elementary school to high school. For this reason it is required to explore it from the perspective of people who are enrolled in a science career path using a qualitative approach (Jones et al., 2011; Maltese et al., 2014). The internal constraints are concerning with the ethical principles followed in the research (Eisenhart & Howe, 1992). The ethical review of this study is based on the principles established by the Finnish National Board on Research Integrity (2009) and is presented in the next subchapter (8.2).

The fifth standard is comprehensiveness. This standard is related to the overall quality of the previous standards and their interaction (Eisenhart & Howe, 1992). In the present study, the previous standards were interacting and considered in the different phases of the research. For example, the ethical principles were followed during the data collection phase and for reporting the results. Moreover, theories and previous research were considered while developing the aim, research questions, and the coding scheme. Furthermore, the aim of the study was based on the need to understand how the interest in science develops (Ainley & Ainley, 2015).

The reliability of this study was ensured by measuring the Cohen's Kappa coefficient that is frequently used for content analysis (Drisko & Maschi, 2015). An independent researcher coded 20% of the data and the inter-rater agreement was significant ($\kappa = 0,81$).

8.2 Ethical Issues

The Finnish National Board on Research Integrity (2009) established ethical principles that were followed in the present study to respect the autonomy of the participants, to avoid harm and to protect their privacy and data.

The emails and/or messages that were sent to invite the participants, stated that participation in this study was voluntary. They were also informed about the research topic, the aim of the

research, the time required for the interview, and the contact information of the researcher. Before starting the interviews and following the interview protocol (Appendix 1), participants were informed again about the aim of the research and the voluntary participation that included the right to stop the interview at any time. They were asked for oral consent to record the interview and, it was also mentioned that they had the option to request the researcher to stop recording at any time or for a specific part of the interview.

Participants were also informed that the personal data will remain anonymous. During the data analysis and the report of the results, the names of the participants, institutions, and people they mentioned were replaced to ensure their privacy and to avoid harm. Participants were also treated with respect during the different phases of the present study.

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Appendix 1

Interview Protocol

Introduction

Good morning/afternoon. My name is Lourdes Malacara, I am a student of the master in Learning, Education and Technology at the University of Oulu. Thank you very much for taking the time to talk with me today. As I mentioned in the (email/message/etc), I am conducting a study for my master thesis that aims to explore the experiences that influenced the development of interest in science. If it is okay with you, I will be audio-recording our conversation, so that I can get all the details and at the same time be able to carry on an attentive conversation with you. If you change your mind for any reason or you do not want me to record a specific part of the interview, I can turn off the recorder at your request. Do you agree to allow me to audio-record this interview? The participation in the study is voluntary, so you can stop the interview at any time. Your personal data will remain anonymous.

Do you have any question?

First, as we are talking about previous experiences, I would like you to mark on this timeline the first time you became interested in science. And, please, take your time to think and mark more experiences that made you interested in science. Let me know when you are ready.	
Background Information: Age: <ul style="list-style-type: none">• Can you tell me about your (higher) educational background (bachelor's degree, master's degree/ PhD)?• Can you tell me what is your current/last work and what do you do?	
1. Can you describe how you first became interested in science? Probes: <ul style="list-style-type: none">-When-Who-What-Why	Alternative Questions. <ul style="list-style-type: none">1. Can you describe how your interest in science began?1. How did your interest in science begin?

<p>2.Can you describe an (another) experience in your childhood that made you interested in science?</p> <p>Probes:</p> <ul style="list-style-type: none"> - An experience at school: type of activity, teacher - An experience out of school - Did you investigate more about the topic/activity? - Do you remember more experiences? Can you give me more examples? <p>3. Did you spend some of your free time doing activities related to science during your childhood?</p> <ul style="list-style-type: none"> - Yes: can you tell me some examples? <p>Probes:</p> <ul style="list-style-type: none"> - games/ experiments <p>4. Can you describe an (another) experience in your adolescence that made you interested in science?</p> <p>Probes:</p> <ul style="list-style-type: none"> - An experience at school: type of activity, teacher, feelings during the experience - Type of activity - Teacher - An experience out of school - Do you remember more experiences? Can you give me more examples? <p>5. Did you spend some of your free time doing activities related to science during your adolescence?</p> <ul style="list-style-type: none"> - Yes: can you tell me some examples? <p>Probes:</p> <ul style="list-style-type: none"> - games/ experiments/ reading about science related topics - can you tell me some examples? - Why did you spend your free time doing these activities? 	<p>2.Can you describe an experience that made you interested in science during primary school?</p> <p>Probes:</p> <ul style="list-style-type: none"> - Type of activities - Teachers <p>Did you have the opportunity to explore science independently during your childhood?</p> <p>-Yes: can you tell me more examples?</p>
<p>6. When and why did you decide to pursue a degree on a science-related field?</p> <p>Probes:</p> <ul style="list-style-type: none"> - Did you have a goal? - What were your expectations? - What did you know about the career opportunities? 	<p>6. What are the main reasons that made you pursue a degree on a science related field?</p> <p>Probes:</p>

<p>7. Was there any time while you were studying that you really thought about leaving the degree?</p> <p>If yes: can you tell me more?</p> <p>Probes:</p> <ul style="list-style-type: none"> - Why did you continue? <p>8. Can you describe an (another) experience in your adulthood that have made you interested in science?</p> <p>9. Who contributed to the development of your interest in science? How?</p> <p>Probes:</p> <ul style="list-style-type: none"> - e.g. parents, teachers, a scientist <p>10. What are the skills and abilities that you think a person working or studying science should have?</p> <p>11. What of those characteristics do you have?</p>	<ul style="list-style-type: none"> - When did you take the decision? - Did you have a goal? - What did you know about the career opportunities?
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Again, thank you very much for your time, it was really interesting to listen to you. About the study, if you require any further information or have any question, feel free to contact me.

Appendix 2

Theme: Social				
Categories	Definition	Subcategories	Example	Based on
Significant people	A person who either through an interpersonal relationship or by being a model provide information or experiences that influenced the participant towards science.	Role models: a person who is observed by the participant and influences him/her throughout his/her behavior, knowledge or success, as an example to follow.	"My father and my grandfather were both scientists' engineers and so they were people I looked up to. As a child, you always go through various phases, but I wanted to grow up to be like my dad"	Jones, Taylor and Forrester (2011), Sjaastad (2012) and Woelfel and Haller (1971)
		Modeling STEM: a person that provides an experience related to STEM or nature.	"Once he [professor] got out this piece of a meteorite and that was one of the coolest things I've never seen, he put some kind of chemical on the top of it and it forms like geometrical forms like lines in the meteorite, and for me was like wow!, because I was like this is out of space, and it was there in our classroom"	
		Definer: a person who through direct interaction with the individual provides information and support.	"The professors who supported me then and who provided me guidance to write papers and submit and then you know because at bachelor's days you don't know about all these things"	
		Others		

Theme: Contextual				
Categories	Definition	Subcategories	Example	Based on
Out-of school experiences	Experiences that influenced the participant towards science and were not related to school.	Science-related games: playing games that involved science content or toys.	"I had toys that were kind of "nerdy". I had this microscope, chemistry set, so that's about my childhood. I would always like to follow the instructions because there were instructions to make invisible [ink] for example"	Dabney, Tai, Almarode, Miller-Friedmann, Sonnert, Sadler and Hazari (2012), Jones, Taylor and Forrester (2011), and data driven.
		Science reading and TV: participants read or watched in the media content related to science.	"I did watch Bill Nye the Science Guy... So he's a very famous science educator and he had this TV show...and it was always aimed towards kids and introducing them to the scientific process. It was it was a fun show. ... But it's been it's been 20 years since I've seen it. It was something that made science tangible"	
School-related experiences	Experiences related to school that influenced the participant towards science.	Tinkering and building: to build something or make changes to repair it or improve it.	"When I was in fifth grade or sixth grade...we needed to make these motors...that we see this electrical wire...yeah you put on battery it will turn, right. We need to make this Motors by ourselves"	Jones, Taylor and Forrester (2011), Maltese & Tai, (2010), and data driven.
		Research and projects: to do a detailed study of a topic to find out new information	"So basically, to be some sort of project that makes use of all the coursework you have taken up to that point and you apply it on some sort of project and so that was really cool"	
		Experimenting: try and test different or new ways to do something.	"I remember this is now back in elementary school trying to grow crystals. I forget how exactly it works. You make some sort of solution then you precipitate a crystal"	
		Class content & materials: subjects, topics and learning materials that are relevant for the participant.	"Studying causes of global warming and things that you can do better, and you know, to lower your impact"	
		Decision making: to have the opportunity to decide subjects and topics to study and the university.	"When I studied, we kind of had the opportunity to pick the minors and courses ourselves. So that was really good because that way I could really pick the things that I was most into"	
Nature-related experiences	Experiences related to nature that influenced	Outdoors experiences: activities that took	"I remember when I was quite young, I remember I used to play outside with ants. Like I would	Data driven

	the participant towards science.	place outdoors and are related to nature.	just observe their nest and I would just like spend hours looking at them. I always thought that animals were very interesting and plants"	
		Nature-related problems: knowledge about environmental issues.	"There is one on a paper that someone did blood analysis of the foxes and find out they are getting diabetes, heart problem that's high cholesterol because the eaten all the trash that we throw it on the floor"	

Theme: Individual			
Categories	Definition	Example	Based on
Self-efficacy beliefs	Perception of his/her own abilities and performance related to science.	"Well when I was 12, there I had chemistry, biology, and I think I had physics and I remember I was really good in chemistry, really good, so as well as in biology"	Bong, Lee, and Woo (2015) and data driven.
Goals	To have a purpose to be achieved.	"I did that I would do groundbreaking research and you know win prizes"	Data driven.
Individual interest	Independent predisposition to reengage with a content over time.	"Then in addition I read things that were related to science from those newspapers and then from some books that I borrowed from a library. I remember that I also borrowed from library some books, and also I discussed about those topics with other persons my schoolmates, yeah and maybe some older mates as well but I think that I read books that that wasn't kind of included for the school. So, I went to the library and I wanted to find something more"	Bong, Lee, and Woo (2015), Hidi and Renninger (2016) and data driven.